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ɪGHWAY AIR QUALITY IMPACT APPRAISALS

Vol. II. Guidance for Highway Planners and Engineers

June 1978

Final Report

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Prepared for

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Washington, D.C. 20590

FOREWORD

This report is the second of a two volume series entitled, "Highway Air Quality Impact Appraisals:" Volume I, "Introduction to Air Quality Analyses;" and Volume II, "Guidance for Highway Planners and Engineers." These two reports are intended to provide transportation planners and engineers with guidance on how to perform air quality analyses.

Volume II is designed to familiarize the highway developer with the issues that must be considered in determining an appropriate air quality analysis method. Technical procedures utilized in transportation planning are presented, and their value in providing input to evaluating the air quality impact of a land use or transportation plan is described.

The reports were prepared during a Systems Applications Incorporated research study conducted for the Federal Highway Administration, Office of Research, Washington, D.C. under Contract FH-11-9143.

Sufficient copies of the report are being distributed by FHWA Bulletin to provide a minimum of one copy to each FHWA Regional and Division office, one copy to each State highway agency, and one copy to each Metropolitan Planning Organization. Direct distribution is being made to the Division offices.

Charles F. Scheffey
Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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16. Abstract
This report is the second of a two volume series titled, "Highway Air Quality Impact Appraisals - Volume I, Introduction to Air Quality Analyses, and Volume II, Guidance for Highway Planners and Engineers." These two reports are intended to provide transportation planners and engineers with guidance in how to perform air quality analyses. This volume presents guidance for transportation planners and engineers on evaluating the air quality impact of a land use or transportation plan. The various laws that require such an evaluation are reviewed. The technical procedures utilized in transportation planning are presented briefly, and their value in providing input for an air quality analysis is described. Techniques for compiling emissions inventories and for predicting resultant air quality are also discussed.

The various issues that arise in evaluating land use plans, transportation policies, and facility and operation plans at both regional and subregional levels are described, including the selection of the appropriate spatial and temporal scales for the analysis, the accuracy necessary in the analysis methods, the application of screening procedures to determine the level of analysis required, the comparison of air quality predictions to legal requirements on air quality, and the reporting of modeling results. The treatment is designed to familiarize the highway planner or engineer with the issues that must be considered and allow him to determine the appropriate analysis method.

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METRIC CONVERSION FACTORS

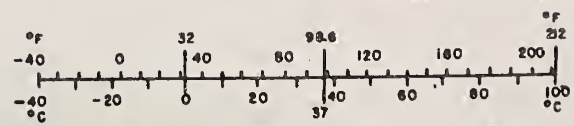
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I INTRODUCTION

The purpose of this volume is to provide guidance for highway planners and engineers in selecting and designing air quality analyses that should be performed as part of a transportation planning project. Included in the scope of this document are definitions of the issues affecting evaluation of air quality impacts, analytical tools that can be used to address these issues, and resources required to apply these methods. For each of these cases, information is presented to support highway planners in selecting the appropriate analysis for a particular planning situation.

A cursory review of the material contained in Volume I of this report [1] will acquaint the reader with the role that vehicular emissions play in the degradation of air quality. In that volume, the effects of vehicular emissions are compared with those of other anthropogenic and natural sources of pollutants. That discussion includes:

> The identity of pollutants of interest.
> Air quality standards.
> Important sources of air pollution.
> Significant temporal and spatial scales of pollutant formation and dispersion.
> Meteorological and chemical processes affecting air quality.
> Availability of data on meteorology, emissions, and air quality.
> Availability of analytical methods for evaluating alternative air quality control plans.

This document draws upon that information in presenting guidance for highway planners in the integration of air quality analysis in the transportation planning process.

Chapter II describes the legal framework within which air quality analyses of transportation plans are performed. Included is a summary of applicable legislation, the administration of this legislation, and the organizational mechanisms involved in satisfying legal requirements. This information is presented to acquaint the reader with what questions must be answered by an air quality analysis, to whom the answers are addressed, and how the results are reviewed by interested parties.

Before highway planners undertake detailed considerations of specific planning problems, they need a general understanding of the available resources for analyzing air quality. These resources include techniques for estimating travel demand, highway usage, both vehicular and nonvehicular emissions inventories, and resultant air quality. Thus, Chapter III briefly reviews these data, tools, and methods. (They are discussed in depth in Volume I of this report.)

The laws and procedures described in Chapter II and the analytical capabilities described in Chapter III establish the basis for air quality analysis in transportation planning and engineering. The effect of these laws is a requirement that air quality analysis be included in the transportation planning process. For the application of air quality analysis methods, the planning process is divided into categories based on the type of geographic area and planning decision under consideration.

The geographic character of the area affects the type of planning that is carried out and the type of decisions that are made. Two primary categories are considered here: regions and subregions. The subregional category is then further subdivided into three classes: subareas, corridors, and specific localities. This results in four different area categories, each of which has characteristic differences in the way in which air quality analysis is carried out.

The purpose of the planning process is to inform decision-makers about the implications of various courses of action and to develop specific implementation programs. For the purpose of this document, decision types are grouped into three categories: land use plans and policies,

transportation policies, and facility and operational plans. Land use plans focus on changes in land use, which in turn affect travel patterns. Thus, transportation planning is indirectly involved in analyzing the implications of land use plans and policies. Transportation policies include the various types of transportation plans that are policy rather than project oriented. These policies may, for example, establish levels of investment in various types of transportation improvements, but they do not set out specific projects. Facility and operational plans specify transportation improvements. Facility plans include new alignments and expansion of existing facilities. Operational plans concern changes in the operations of existing facilities.

This classification by type of area and planning decision leads to three types of analysis within the context of regional planning and a total of nine for the three levels (subarea, corridor, and specific locality) of subregional planning, as shown in Table 1. Within each category, the specific technical questions addressed by air quality analyses are raised, and the alternative approaches for providing answers are reviewed. The key issues in selecting the most appropriate method are discussed in detail to provide highway planners with a sufficient understanding of the air quality analysis process to decide which approach should be followed in any given situation. For example, in the context of evaluating a land use plan at the regional level, the discussion includes sections dealing with population growth patterns, traffic distribution among various transportation modes, assignment of travel demand to a highway network, estimation of regional emissions from both vehicular and nonvehicular sources, and air quality modeling. These sections are linked by the common consideration of the nature of the specific land use plan being considered and the appropriate spatial resolution of the analysis. The thrust of the material is to indicate the balance between accuracy and cost. The other planning categories are treated similarly, discussing available resources, required results, and the various factors affecting selection of an appropriate methodology.

Chapters IV and V discuss regional and subregional planning, respectively. In both cases, the chapters begin by defining the size and other geographical

characteristics of the particular type of planning area and by describing its internal jurisdictional organization and its relationship to external jurisdictions. The discussions then review the nature of air quality problems in terms of pollutants, scales, averaging times, meteorological conditions, and air quality standards that are relevant for the type of planning area being treated. The resources available for analyzing air quality at the relevant scales are described, including technical procedures and data requirements for demographic and traffic forecasting, emissions estimation, and air quality modeling. The chapters then consider the selection of specific procedures used in air quality analyses. For simple situations, the applicable procedures are described in detail in this volume. For the more complex applications, the issues are instead described to provide highway planners with a full understanding of the questions that need to be answered and the steps likely to be followed in providing these answers. Thus, together with Volume I, this manual is designed as a guide to the air quality legal requirements and administrature procedures to which highway planners respond and to the technical procedures required for a legally adequate and technically sound air quality impact evaluation.

TABLE 1. THE 12 CATEGORIES OF TRANSPORTATION PLANNING ANALYSIS

		Subregional Planning		
Type of Planning Decision	Regional Planning	Subarea	Corridor	Specific Locality
Land use planning	X	X	X	X
Transportation policies	X	X	X	X
Facility and operational plans	X	X	X	X

II AIR QUALITY AND TRANSPORTATION

This chapter discusses the role of air quality in the development of transportation plans and programs. Legislative aspects of air quality are summarized, and then the pertinent relationships between air quality legislation and the transportation planning process are outlined. Brief comments are given on the organizational structures within which transportation decisions are made. Finally, the transportation planning process itself and the role of air quality analysis in the development of transportation programs are discussed.

A. LEGISLATION

Federal and state legislation takes the form of statutes, regulations, policies, and procedures, each having specific implications:

> <u>Federal or state statutes</u>. These are laws passed by the U.S. Congress or by state legislatures. They can be enforced in a court of law by any members of the public who can show that they have been or will be damaged by the failure of a government agency to comply with the statutes. Examples of such statutes are the Federal-Aid Highway Act, The Clean Air Act, and The National Environmental Policy Act.

> <u>Administrative regulations</u>. These are rules promulgated by government agencies that have been authorized by Congress or another legislative body to develop rules of conduct in specified areas. For example, the EPA is authorized and required by The Clean Air Act to develop rules to ensure that the National Ambient Air Quality Standards (NAAQS) are achieved and maintained. Similarly, the Council on Environmental Quality (CEQ) is responsible for the manner in which Environmental Impact Statements (EIS) are to be prepared. Administrative regulations can be enforced in a

court of law by any members of the public who can show that they have been or will be damaged by the failure of a government agency to comply with the rules.

> Policies, procedures, and manuals. These consist of instructions developed by a government agency to establish procedures that employees of the agency should follow to comply with statutes or regulations. For example, the Federal Highway Administration's "Federal-Aid Highway Program Manual" contains policies and procedures setting forth the manner in which their Environmental Impact Statements should be prepared [2]. Such procedures are not generally enforceable by a court of law. However, in challenges of an agency action or decision, failure to comply with the procedures can be used as evidence that the agency has failed to fulfill its obligations properly.

1. Legislation Affecting Air Quality and Transportation

The principal federal legislation related to air quality and transportation is summarized in Table 2, and brief abstracts of each are contained in the appendix. These statutes, orders, and regulations affect three major aspects of transportation program development:

> Transportation and highway planning--procedures and requirements relating to the incorporation of air quality considerations in the planning process.

> Disclosure and dissemination of information--hearings, review mechanisms, and EIS preparation.

> Air quality and requirements--air quality impacts and consistency with air quality requirements.

Although the first category is the most directly related to transportation planning, all at least indirectly influence the planning procedures and review process. Brief comments on the key legislative items are given below.

TABLE 2. SUMMARY OF LEGISLATION AFFECTING AIR QUALITY AND TRANSPORTATION

Legislation	Year	Air Quality Standards	Vehicle Emission Controls	Organizational Mechanisms	Planning Procedure	EIS Requirements or Guidelines
Federal statutes						
The Air Pollution Act of 1955 (P184-159)	1955			X	X	
Federal-Aid Highway Act of 1962 (23 U.S.C. 134)				X	X	
The Clean Air Act of 1963 (PL88-206)	1963	X		X	X	
Urban Mass Transportation Act of 1964 (49 U.S.C. 1610)	1964			X		X
The Motor Vehicle Air Pollution Control Act (PL87-272)	1965		X	X	X	
The Department of Transportation Act (PL89-670, 49 U.S.C. 1651 et seq.)	1966			X	X	
The Air Quality Act of 1967 (PL90-148)	1967	X		X	X	
The National Environmental Policy Act of 1969 (PL91-190, 42 U.S.C. 4331 et seq.)	1969			X		X
The Clean Air Act of 1970 (PL91-604, 43 U.S.C. 7400 et seq.)	1970	X	X	X	X	X
Federal-Aid Highway Act of 1970 (8a, 23 U.S.C. 101 et seq.)	1970					X
The Clean Air Act Amendments of 1977 (PL95-95, 42 C.F.R. 51641)	1977	X	X	X	X	X
Executive Orders of the President						
Protection and Enhancement of Environmental Quality	1970					X
Executive Order 11514	1977					X
Executive Order 11991	1977					X
Code of Federal Regulations						
National Highway Traffic Safety Administration, "Motor Vehicle Emission Inspections," 49 C.F.R. 590	1975		X			
Environmental Protection Agency, "National Primary and Secondary Ambient Air Quality Standards," 40 C.F.R. 50	1976	X				
Environmental Protection Agency, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans," 40 C.F.R. 51	1976			X	X	X
Environmental Protection Agency, "Approval and Promulgation of Implementation Plan," 40 C.F.R. 52	1976			X	X	X
Environmental Protection Agency, "Prior Notice of Citizen Suits," 40 C.F.R. 54	1976			X		X
Environmental Protection Agency, "Energy Related Authority," 40 C.F.R. 55	1976	X		X		
Environmental Protection Agency, "Regulation of Fuels and Fuel Additives," 40 C.F.R. 80	1976		X			

TABLE 2 (Concluded)

Legislation	Year	Air Quality Standards	Vehicle Emission Controls	Organizational Mechanisms	Planning Procedure	EIS Requirements or Guidelines
Environmental Protection Agency, "Air Quality Control Regions, Criteria, and Control Techniques," 40 C.F.R. 81	1976			X	X	
Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines," 40 C.F.R. 85	1976		X			
Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines: Certification and Test Procedures," 40 C.F.R. 86	1976		X			
Council on Environmental Quality, "Preparation of Environmental Impact Statements: Guidelines," 40 C.F.R. 1500	1976					X
Council on Environmental Quality, "Regulations on National Environmental Policy Act" (proposed regulations)	1977					
Federal Highway Administration, "Process Guidelines (for the Development of Environmental Action Plans)," 23 C.F.R. 795	1977					X
Department of Transportation orders						
Procedures for Considering Environmental Impacts (DOT 05610.1B)	1974				X	X
Federal-Aid Highway Program Manual						
"Urban Transporation Planning Process" (F-AHPM, V.4,C.4,S.2, 23 U.S.C. 104(F)(3), 134, 315)	1975			X	X	
"Air Quality Guidelines" (F-AHPM, V.7,C.7, 23 C.F.R. 770)	1976			X	X	X
"Environmental Impact and Related Statements" (F-AHPM, V.7,C.7,S.2, 23 C.F.R. 771)	1976					X

a. The Clean Air Act

The primary legislation related to air quality requirements is the 1967 Clean Air Act together with the 1970 and 1977 amendments to the act. Various regulations, such as 40 C.F.R. 51 ("Requirements for Adoption and Submittal of Implementation Plans") have been promulgated by the Environmental Protection Agency pursuant to the act.

The 1970 act, which combined all previous air quality and emissions acts, called for the establishment of primary and secondary National Ambient Air Quality Standards. Also, it required the EPA to set standards of performance for new stationary sources of pollution and for motor vehicles. The act required states to prepare State Implementation Plans (SIPs) by 30 January 1972 for meeting and maintaining the NAAQS within three years. According to the act, the EPA administrator shall approve those air quality implementation plans if they include:

> . . . emissions limitations, schedules, and timetables for compliance with such limitations, and such other measures as may be necessary to insure attainment and maintenance of such primary or secondary standards, including, but not limited to, land use and transportation controls [3].

In 1977, Congress amended The Clean Air Act to set 1982 as the compliance deadline, with possible extensions to 1987 for automobile-related pollutants (oxidant and carbon monoxide). Although the amendment granted the states a 5- to 10-year extension, it also provided federal assistance to secure compliance with the planning requirements of the act. Federal action can be taken if states do not meet the new deadlines or do not demonstrate reasonable efforts toward submitting such plans by 1 July 1979. Actions can also be taken if plans submitted in 1982 do not meet all federal requirements; when extension to 1987 is requested, these plans must also include a vehicle emission inspection-maintenance program.

As a result of a court decision in 1973 (National Resources Defense Council v. Environmental Protection Agency, 475 F.2d 968), states are required to develop maintenance as well as implementation plans. These Air Quality Maintenance Plans (AQMPs) are required in areas that have already attained compliance with the standards but need controls to ensure that the standards are maintained.

b. The Department of Transportation and Federal Highway Acts

Many of the current transportation planning mechanisms have evolved out of the Department of Transportation Act (49 U.S.C. 1651 et seq.), the Urban Mass Transportation Act (49 U.S.C., "Transportation"), and the Federal Aid Highway Act (23 U.S.C., "Highways"). Since 1962, the Federal-Aid Highway Program has required that proposed highway projects receiving federal support in urban areas having more than 50,000 population be based on a continuing, comprehensive transportation planning process in which states and local communities cooperate. The requirement that the process be "continuing, comprehensive, and cooperative" has caused the program to become widely known as the "3C process."

The Department of Transportation Act directs the Secretary of Transportation to cooperate with other federal agencies and the individual states "in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the land traversed." Pursuant to 23 U.S.C. 109(h), the Secretary of Transportation is directed to develop guidelines to ensure that adverse environmental effects of any proposed highway project will be fully considered before approval of that project.

Regulations pursuant to 23 U.S.C. 109(j), as set forth in the "Federal-Aid Highway Program Manual," require that transportation planning be coordinated with air quality planning pursuant to 42 U.S.C. 1857 (Clean Air Act). Furthermore, the highway agency must request the "3C" policy board to assess annually the consistency of the current transportation plan with the State Implementation Plan. The results are subject to annual

review by the Regional Federal Highway Administrator in consultation with the EPA Regional Administrator.

Other regulations promulgated by the FHWA pursuant to 23 U.S.C. 109(h) require that each highway agency develop an "action plan" describing the organization to be set up and the process to be followed in the development of federal-aid highway projects from initial system planning through design. Legislation on certification acceptance provides that state law may apply to individual highway projects where 23 U.S.C. previous applied, relieving the FHWA of certain administrative actions. Obligations under the National Environmental Policy Act, Section 4(f) of the DOT Act, and The Clean Air Act cannot be delegated to the states. Requirements outlined in 23 U.S.C. 134 have also been excluded from certification acceptance by administrative decision.

c. Environmental Impact Assessment

Legislation relating to dissemination of information in the highway development process is contained in The National Environmental Policy Act of 1969 and Executive Order 11514, which implemented its requirements. This act, commonly known as NEPA, requires that a detailed Environmental Impact Statement be prepared for "major Federal actions significantly affecting the quality of the human environment. . . ." The EIS must address five areas of concern:

- The environmental impact of the proposed action.
- Any adverse environmental effects that cannot be avoided if the proposal is implemented.
- Alternatives to the proposed action.
- The relation between local, short term uses of the human environment and maintenance and enhancement of long term productivity.
- Any irreversible and irretrievable commitments of resources required by the proposed action.

NEPA also established the Council on Environmental Quality, which serves two basic functions: (1) reporting to the President on environmental matters and (2) coordinating federal programs relating to environmental policy and developing guidelines for preparation and issuance of Environmental Impact Statements.

NEPA allows the delegation of EIS preparation to the states, but requires input and close supervision by the responsible federal agency. Specifically, the agency must furnish guidance for and participate in the preparation of the EIS. All other state and federal agencies affected must be notified of the proposed project, and the EIS must be evaluated by them before the project is approved.

Draft CEQ regulations to replace current guidelines were required by Executive Order 11991, and the changes may affect the highway approval process. One new feature in the proposed guidelines is a preliminary review mechanism called the "scoping process." Prior to preparation of the EIS and before decisions are made that might foreclose alternatives, the proposing agency must hold a "scoping meeting" to determine the scope of significant issues to be analyzed in the EIS. All federal, state, and local agencies affected, along with all other interested persons, must be invited to participate. Guidelines for implementation of this new review process are to be issued by the FHWA within eight months after adoption of the proposed CEQ regulations.

2. Legal Implications of the Planning and Review Process

The various statutes, regulations, policies, procedures, and guidelines require certain procedures in the transportation planning process. Failure to follow the legal mandates can result in a court ruling declaring that the planning process has been improperly conducted and, hence, that the planning decision cannot be implemented. Since most litigation relating to transportation planning does not begin until completion of the planning process, a ruling that the planning process has been unlawfully conducted and that a project cannot be implemented could require the entire planning process to be repeated.

Some of the principal planning steps that may be questioned in court actions are:

> Public hearings. Meetings need to be scheduled early enough to assure the public of an opportunity to affect a decision in the process of being made rather than only to comment on a decision that has already been made.

> State-of-the-art analysis techniques. Differences of opinion among experts should be fully disclosed. If such differences have been disclosed, the court can conclude that the transportation agency did not ignore conflicting opinions, but rather, seriously analyzed them and selected a particular approach because of its greater merit.

> Disclosure of criticisms of the proposed project. Criticisms should be presented to the public together with reasoned responses.

> Interdisciplinary analysis approach. Such an approach implies that persons trained in differing disciplines work together to identify issues relating to the project and to develop solutions to problems. (In contrast, a multidisciplinary approach combines input from persons of different disciplines but does not necessarily mean that they work together in identifying issues and solving problems.)

> Analysis of feasible alternatives to the proposed action. It should not be concluded summarily at the outset that new or innovative alternatives are infeasible.

> Planning assumptions. Projections of demographics, growth patterns, and growth-affecting impacts of the proposal should be the best that are available, and the underlying assumptions need to be fully described.

In each of these areas, differences of opinion can occur as to what is important, relevant, practical, and feasible. The main forums in which the differences of opinion are discussed are public hearings, the "scoping" procedure (assuming that it is adopted), the preparation of Environmental Impact Statements, and responses to comments to an EIS. When the process

is open, thorough, and productive of disclosure, the transportation agency has considerable discretion in selecting among alternative points of view. Therefore, it is important that the planning procedures enable the mandates to be followed and that positive answers can be given to each of the potential questions that the court may consider.

B. ORGANIZATIONAL AND ADMINISTRATIVE MECHANISMS

Mechanisms for incorporating air quality into planning programs are related to the air quality legislation discussed previously. As a result of the legislative enactments, the responsibility for air quality analysis is shared among local, state, and federal government agencies. For example, on most federal-aid urban highway projects, basic planning occurs at the local level and is then subject to review by state and federal agencies. The following sections describe the organizational framework in which planning takes place and the various planning mechanisms available.

1. Organizational Framework

Most highway projects are initiated by the planning actions of a local metropolitan planning organization, other local agencies, and the state highway agency. Federal government participation in the transportation planning process occurs mainly through the U.S. Department of Transportation through the Federal Highway and Urban Mass Transportation and Federal Aviation Administrations. All actions of the local, state, and federal agencies that significantly affect air quality are subject to review by the Environmental Protection Agency. In cooperation with the various affected DOT administrations and the U.S. Department of Housing and Urban Development, the EPA assumes some responsibility for area-wide planning.

2. Transportation Planning Mechanisms

Transportation plans are prepared for a variety of reasons and within a variety of organizational contexts. The classification into the 12 different categories described in Chapter I provides a convenient format for examining

the different types of transportation planning situations in relation to air quality analysis. These categories describe the types of decisions being made and the geographical context within which the planning mechanism operates.

Many transportation plans arise from legislative requirements and are part of a continuing transportation planning process (as distinct from a specific project plan). Because of the importance of these mandated plans, they are summarized here to indicate the type of transportation planning mechanisms currently required.

a. The "3C" Process

In urbanized areas, all federal-aid projects must be based on the 3C process as a prerequisite to approval (23 U.S.C.) to ensure that all federal, state, and local planning resources are effectively used. The urban transportation planning process includes the development of a prospectus and a Unified Work Program. The prospectus, formerly known as an operations plan, is an overview of the planning process. It does not require an annual update, but is kept current as conditions change. The State, as a partner in the planning process, ensures that the prospectus delineates currently valid organizational responsibilities, operating procedures, and general planning overview. The unified planning work program is responsible for:

> Annually describing all urban transportation and transportation-related planning activities anticipated within the area during the next one- or two- year period regardless of funding sources.
> Documenting work performed with planning assistance provided under Section 9 of the Urban Mass Transportation Act [49 U.S.C. 1607(a) and 23 U.S.C. 104(f), 307(c)].

The transportation planning process also includes the development of a long range strategy that:

> Provides for the long range transportation needs of the urbanized area.
> Identifies new transportation policies and transportation facilities or major changes in existing facilities by location and modes to be implemented.

In addition, it includes a Transportation Improvement Program and a Transportation Systems Management element, as described below.

b. <u>The Transportation Improvement Program</u>

This program is mandated under joint FHWA and Urban Mass Transportation Administration rules and regulations issued in September 1975. It is prepared by urbanized areas to indicate annual and three- to five-year components of highway and transit projects. Part of the program regulations require that long range transportation planning be performed by metropolitan planning organizations and that the program be consistent with these long range plans. Thus, this program combines both highway and transit projects into the overall planning program.

c. <u>Transportation Systems Management</u>

The Transportation Improvement Program regulations require that programs selected from the Transportation Systems Management element be included in the program to provide for the short range efficient movement of people. Transportation Systems Management provides strategies for maximizing the use of existing facilities and emphasizes actions that have low capital cost requirements.

d. <u>State Implementation Plans</u>

The Clean Air Act of 1970 requires each state to develop implementation plans to attain and maintain the National Ambient Air Quality Standards. Transportation strategies can be included in these plans. For example, the draft EPA/DOT guidelines state that:

> Preparation of implementation plans for nonattainment areas is to be coordinated with the continuing, cooperative, and comprehensive transportation planning process required under 23 U.S.C. 134 [Section 174(b) of the Clean Air Act].
> The air planning activities should be included in the Unified Work Program required by the Department of Transportation [4].
> The adopted transportation measures should be included in the required Transportation Improvement Program [4].

Specific requirements for developing plans in nonattainment areas are spelled out in Section 172 of The Clean Air Act:

> Reasonable notice and public hearings.
> Implementation of reasonably available control technology on existing pollution sources in the area.
> Demonstration of reasonable further progress* toward attainment with initial plan submittal in 1979.
> A comprehensive inventory of actual emissions.
> Identification of and provisions for emissions from construction and operation of major new or modified stationary sources.
> Procedures for applying for permits for new and modified major emissions sources, with authority to deny such permits if source emissions will interfere with attainment or maintenance of standards.
> Identification and commitment of manpower and resources for plan implementation.
> Emissions limits and compliance schedules.
> Evidence of public, local government, and state legislative involvement.

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* As defined by Section 171(a), the term "reasonable further progress" means annual incremental reductions in emissions of the applicable air pollutant (including substantial reductions in the early years following approval or promulgation of the plan and regular reductions thereafter) that are sufficient in the judgment of the EPA Administrator to provide for attainment of the applicable National Ambient Air Quality Standard by the date required in Section 172(a).

- > Demonstration that all reasonable measures cannot attain standards by 1982 as a condition for 1987 extension. Under this condition, the following must also be included:
  - An analysis of alternative sites, sizes, production processes, and environmental control techniques for construction or modification of a major emitting facility.
  - Establishment of a schedule for implementation of an inspection-maintenance program for motor vehicles.
  - Identification of other measures necessary to attain the standards by 1987.
- > Demonstration of legal authority to implement the plan's provisions.

e. <u>Action Plan Program</u>

The Action Plan Program developed by the FHWA was designed to ensure that adequate consideration is given to possible social, economic, and environmental effects of proposed highway projects and that the decisions concerning such projects are made in the best overall public interest. Under the FHWA program, each state transportation agency is required to develop an action plan that provides for:

- > Identification of social, economic, and environmental effects.
- > Greater involvement of the public and other agencies in transportation planning and decision-making.
- > Greater use of the interdisciplinary process.
- > Better consideration of alternatives in transportation planning.

C. INTEGRATION OF AIR QUALITY ANALYSIS WITH TRANSPORTATION PLANNING

The transportation planning process is concerned with achieving various transportation objectives. Proposals are developed, the implications of the proposals are analyzed (such as how well the proposed activities will

meet the objectives), and plans are established for implementing the proposed actions. The process is often iterative as alternatives are analyzed and evaluated to reach the best solution under the constraints imposed.

The incorporation of air quality concerns in this type of transportation planning process is depicted in Figure 1. In an impact analysis, the air quality analysis identifies the air quality implications of the particular land use/transportation proposals from travel forecasts. In contrast to such impact analyses, air quality constraints can be included a priori in the planning process. In this situation, air quality would be the basis for determining allowable emissions and hence total travel at a predetermined level instead of being an impact to be analyzed in the process. In either case the process depicted in Figure 1 would still be followed, and the same decision point would be reached when the air quality forecasting process is used to determine whether air quality objectives are in fact being achieved. If not, then the process would return to consideration of modification of land use or transportation proposals.

The link between the transportation and air quality aspects of the transportation planning process is in the determination of mobile emissions. Traffic forecasts are converted to predictions of emissions levels, which in turn are used in the air quality forecasting process to estimate air quality. As discussed in detail in Volume I, emissions are determined from five basic descriptors of travel:

> Vehicle-miles (the amount of traffic)
> Peak and off-peak speeds
> Level of service (degree of congestion)
> Cold starts and hot soaks
> Vehicle mix.

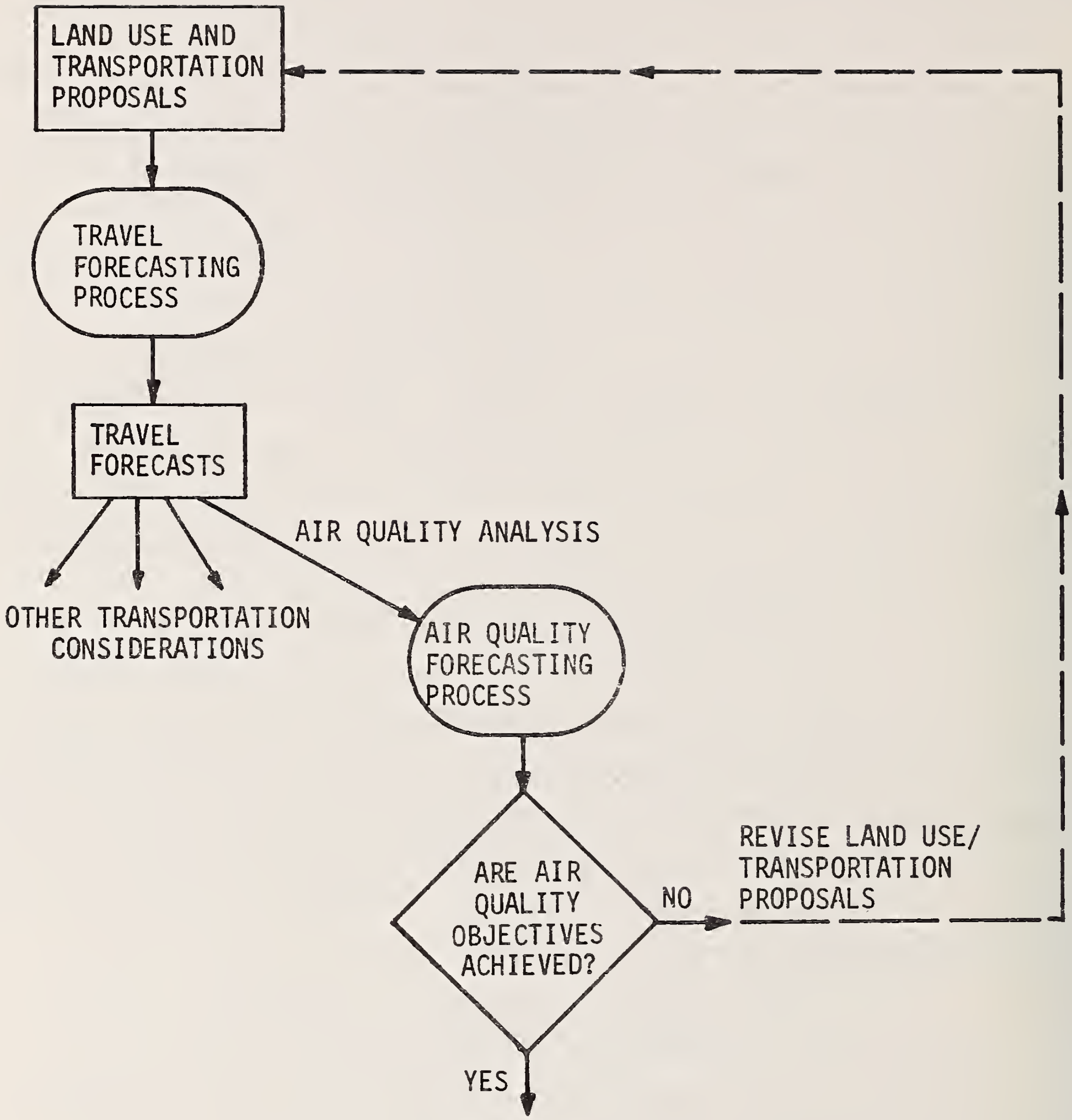


FIGURE 1. INTEGRATION OF AIR QUALITY ANALYSIS WITH TRANSPORTATION PLANNING

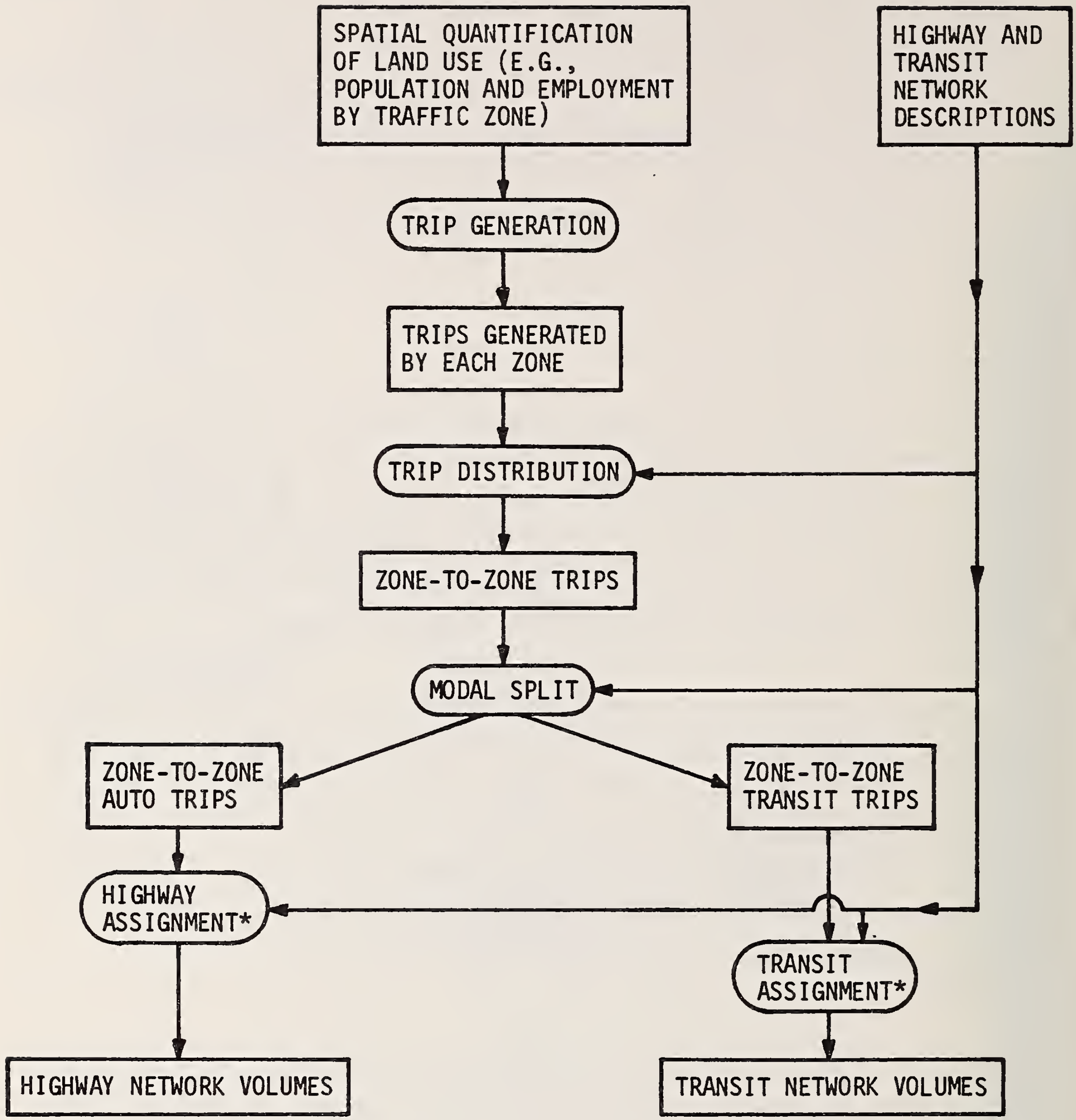
The descriptors are spatially defined (e.g., on network or grid cells) so that the resulting emissions are likewise spatially defined. The average speed and vehicle mix can be used to determine the appropriate emissions factors, which combined with vehicle-miles traveled yield estimates of emissions (see the methodology presented by the EPA in Supplement 5 of its Publication AP-42 [5]). More precise estimates of emissions factors can be obtained by considering level of service as well by using the methods outlined in the appendix to Volume I of this report.

D. THE TRAVEL FORECASTING PROCESS

Since transportation planning requires an analysis of land use and transportation changes, some form of forecasting ability or transportation model is needed to estimate travel demand. The basic function of a transportation forecasting model is to provide a mathematical representation of travel demand. By utilizing the various relationships between travel and the factors affecting it, future demand can be projected.

At the regional level, transportation models are necessarily complex because they must attempt to simulate the regional transportation system and the travel that occurs on this system with the regional land use pattern. Although the guidelines given in this manual are not intended to provide an extensive discussion on modeling techniques, a brief and generalized description is given below so that terms such as "trip distribution" and "modal split" are defined sufficiently for later reference.

The basic transportation modeling process can be depicted as shown in Figure 2. The land use representation entails spatial quantification of the land use pattern. In transportation planning, the land use specifications required for travel forecasting are called socioeconomic forecasts, which include demographics (e.g., population, dwelling units) and measures of industrial and commercial activity (e.g., employment, floor space). These variables are quantified in relation to their spatial distribution. Generally, some form of zoning pattern is set up, such as census tracts or



* Vehicle occupancy and peak-hour allocation are generally included here either before or after actual network assignment.

FIGURE 2. TYPICAL TRANSPORTATION MODEL STRUCTURE

traffic zones, and the various data items are quantified for each zone. Likewise, the representation of the transportation system provides a spatial quantification of network linkages, travel speeds, and so forth. The travel forecasting process then uses these representations to determine the corresponding travel patterns.

The components of the travel forecasting portion of the overall modeling process are described below:

> Trip generation. This component determines how much traffic is actually generated by the various land uses in each portion of the region. Essentially, trip generation models are based on the premise that all places of human activity can be classified according to land use type and that such land use or activity types uniquely determine the amount of travel activity that is generated.

> Trip distribution. Procedures for trip distribution estimate the spatial characteristics of travel. This is the portion of the forecasting process that recognizes that travel is made up of trips, each with an origin and destination. Trips generated in each portion of the region/subregion are thereby linked together to form a set of regional/subregional travel patterns.

> Modal split. This process estimates how trips are distributed among the different modes (typically auto versus public transit, but some applications involve more complex situations, such as "park and ride" and transit access).

> Auto occupancy. The proportion of auto passengers relative to drivers must be known in many modeling applications, particularly when total person-trips rather than vehicle-trips are estimated in the trip generation process. The auto occupancy procedure converts person-trips into vehicle-trips.

> Time distribution. The time periods over which trips occur, together with the mix of trip purposes and other relevant factors (such as land use), are used to identify temporal patterns for daily travel.

> Assignment. This component, which follows directly from trip trip distribution, determines how trips actually "use" a transportation network. Assignment simulates the routes that would be taken by the different sets of trips produced in the trip distribution process, and it hence gives network volumes.

Specific applications may utilize any or all of the components shown in this diagram, and various techniques are available for the actual processes involved in each. In typical applications, the process may be applied at successively fine levels of detail. Initially, a type of sketch planning or policy level analysis might be undertaken to establish some of the basic directions to be examined in the detailed analysis. The more detailed analysis could then consider the region or area as a whole; then as a third stage, the analysis could focus on specific subregions.

For subregional analysis, a subregional forecasting model can be developed as a subset of the regional model simply by increasing the level of detail in the subregion. In cases where subregional analysis is desired in the absence of a regional modeling capability, the external aspects of the subregional traffic characteristics must be considered along with those relating only to the subregion itself.

E. SUMMARY

This chapter has reviewed the basic federal legislation regarding air quality analysis in transportation planning. An overview of the administration of these laws has been presented, and the planning procedures and mechanisms for their implementation have been outlined. Although individual states may have different laws and different methods of implementing federal laws, the material in this chapter is generally applicable. In addition, this chapter has introduced the key features of the transportation planning process and the integration of air quality analysis within it.

In response to legal requirements for evaluation of the air quality impacts of various types of proposals, including transportation plans, considerable effort has been invested over the last two decades in developing analytical methods for predicting air quality. These methods, when applied to the laws discussed in this chapter, form the basis of air quality analysis in transportation planning. The following chapter discusses the application of the air quality impact analysis methods.

III REVIEW OF AVAILABLE RESOURCES FOR ANALYZING AIR QUALITY

As summarized in this chapter, a variety of data and analytical resources are available for the air quality assessments needed for transportation planning: analysis techniques for estimating emissions; ambient air quality data; historical meteorological data; and air quality predictive models. (For a more detailed discussion, the reader is referred to Volume I of this report.) For some situations, these resources may be more than sufficient to support the required analysis. However, deficiencies in the amount of data available, the adequacy of the various analytical tools, or the ability to forecast traffic patterns may pose planning problems. Although highway planners must make the best use of the available resources, they must also understand the limitations of air quality analyses imposed by less than adequate resources.

The common link among the various analytical tools used in estimating traffic levels, emissions rates, and resultant pollutant concentrations is the spatial and temporal resolution of the analysis and the resources required for its execution. In applying these methods to a set of transportation planning alternatives, one must decide upon the resolution of the analysis needed for the types of decisions under consideration and the availability of data and other technical resources for the analysis.

Selection of the appropriate spatial resolution begins with an examination of the likely effects of the proposed plan. If significant spatial redistribution of emissions in the area is likely, the transportation, emissions, and concentration prediction phases of the work should consider spatial variations. In contrast, if spatial shifts are not likely, analytical techniques that rely on greater aggregation of the data and that produce coarser spatial resolution in the results can be

used. Thus, a lower level of spatial resolution (e.g., a large grid box size) can be used in evaluating a land use plan than that needed to evaluate a facility or operational plan having easily estimated effects on traffic levels. The guiding principle is to select a resolution for the analysis that is consistent with the accuracy and resolution of the available inputs (emissions data and forecasts, air quality and meteorological data).

Temporal resolution is determined by the air quality standard under consideration. Federal standards dictate that carbon monoxide be evaluated using one- and eight-hour averages under worst-case assumptions, NO_2 using annual averages, hydrocarbons on the basis of three-hour averages from 6:00 to 9:00 a.m., and oxidants by a one-hour average. In addition, there are federal standards for suspended particulates based on 24-hour averages and annual geometric means, though vehicles usually are not major causes of violations of these standards at the regional level. State air quality standards may vary from these federal standards. Ordinarily, long term trends are evaluated in terms of their estimated time of completion (ETC) and ETC + 20 years, but intermediate years in which higher pollutant concentrations are likely should also be considered.

The availability of data is a binding constraint on the type of analysis that is feasible. Collecting the type and scope of data required for regional analyses can entail considerable time and expense. Transportation and emissions data sources include the EPA, state and local air pollution agencies, state and local transportation planning agencies, public utilities, and other major point sources. In addition, a field program may be deemed necessary to collect the data required for a technically sound evaluation of an important proposal, particularly for subregional air quality analyses. Even so, the data base may not be adequate for application of the more complex air quality models without introducing assumptions and occasional guesses that weaken the accuracy of the predictions.

Thus far the discussion of the spatial and temporal resolution of the analysis has not considered the feasibility of acquiring the funds, facilities, and personnel needed for the various alternative analytical methods; nor do they account for the financial/environmental impact of the planning decision. In some cases, these issues may dominate the decision. There are major differences in cost among techniques that include spatial resolution, those that require computing facilities, and those that demand specialized training techniques, and those that do not.

A. ANALYSIS TECHNIQUES FOR ESTIMATING EMISSIONS

As mentioned earlier, emissions are the link between travel forecasts and air quality forecasts. Estimation of emissions requires two main steps: compilation of emissions inventories for current sources and forecasting future emissions.

1. Emissions Inventories

For analyses at the regional or subregional level, compilation of an emissions inventory is necessary for both vehicular and other sources. The vehicular component of the inventory is compiled from traffic data, projections, or both at the level of resolution preselected for the analysis. The nonvehicular portion of the inventory is compiled from a variety of data sources, including individual reports for major point sources, rough estimates for population-distributed sources such as space-heating and backyard burning, and estimates of other emissions based on general commercial and industrial activity. Details of procedures for compiling inventories are presented in the EPA's AP-42 report [5] and are summarized in Volume I.

a. <u>No Spatial Stratification</u>

If the analysis is to be region-wide without spatial stratification, emissions estimates can be found in the EPA's national emissions reports [6], which are divided into five pollutant categories: particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. These data are available for the nation as a whole, individual states, portions of some states, and air quality control regions. These numbers are then adjusted in accordance with the proposed changes and projected growth to evaluate the effects of the plan under consideration. This relatively simple procedure requires no specialized equipment and personnel from the transportation planning agency, but the outcome is an adequate inventory for situations in which neither spatial nor temporal resolution is required. Some emissions data, such as those from continuously monitored point sources, will be quite accurate (vehicular emissions inventories are probably accurate within about 30 to 50 percent), while other categories may be off by a much wider margin. On the whole, accuracy is probably within 50 to 100 percent. (These estimates of accuracy are merely educated guesses and should not be construed as anything more.)

b. <u>Spatial Stratification</u>

When spatial resolution is required, estimation of emissions becomes more complex. In some major cities (e.g., St. Louis, Los Angeles, Denver, and San Francisco), spatially stratified emissions inventories have been compiled for specific air pollution research projects. The methods used in each case differ somewhat in detail and degree of automation, but all were designed to yield emissions estimates on a relatively fine rectangular grid. Developing this type of inventory may require up to a year of effort. The details of procedures for compiling this type of inventory appear in Volume I. This suggests that the process of selecting

the appropriate air quality analysis procedures must consider the availability and scope of existing emissions inventories.

c. Temporal Variation

For certain analysis methods, it is necessary to include variations on a daily and/or seasonal basis. If temporal variation is to be included, the transportation models should provide temporal predictions. The National Emissions Data System, which estimates emissions totals for each AQCR for both vehicular and nonvehicular sources, does not include temporal stratification in its reports; however, local air pollution agencies may have such data on hand. If not, one must consider the operating hours of industrial and commercial sources, daily profiles of electrical generation, time patterns of home heating, and the like to produce the required estimates.

d. Accuracy

The vehicular portions of the inventory are based either on the output of transportation models or on detailed traffic counts and estimates of the vehicle mix and associated emissions factors. The nonvehicular portion is based on the individually catalogued major point sources and on estimates of industrial, commercial, and residential activities. The vehicular and nonvehicular estimates are somewhat limited in accuracy because of several factors:

> Vehicular
   - Uncertainties in basic assumptions, such as land use forecasts.
   - Errors in transportation forecasting models.
   - Inaccuracies in emissions factors.
   - Variations from the average vehicle mix.

> Nonvehicular
  - Impossibility of measuring emissions other than those of individually identified point sources.
  - Inaccuracies in emissions factors.
  - Difficulty in precisely locating area-distributed sources.
  - Infrequent updating of estimates.

The inaccuracies are taken into consideration in air quality analyses by making conservative assumptions about emissions and meteorology and by the margin of safety inherent in each air quality standard.

Highway planners should bear in mind two basic questions in considering the emissions assessment for a particular project: First, how accurate must the emissions inventory be to support the air quality analysis, and what are the required temporal and spatial resolutions? Second, given estimates of projected emissions expected as a result of the new project and their magnitudes with respect to current levels, is an air quality analysis needed or not? Clear-cut answers to these questions do not exist, but certain procedures may be of use to planners in attempting to resolve them. These issues are discussed further in Chapters IV and V.

2. Emissions Forecasts

a. Screening

Unfortunately, construction of even a current grid-based emissions inventory is not simple, and it is far from an exact science because the results cannot be directly validated. These problems are amplified when a 20-year planning horizon is considered. Owing to the amount of work required to construct alternative emissions inventories for analyzing land use plans, the number of cases to be evaluated should be limited. The most promising method for such limitation is preliminary screening of the alternatives to determine which choices appear to have the lowest probability of producing adverse impacts on air quality.

Then if a detailed air quality analysis indicates that the best alternative will create unacceptable air quality, it may be safely assumed that the others are unacceptable as well.

b. Selection of Grid Size

It is desirable to formulate the projected emissions inventories at a level of spatial and temporal resolution commensurate with that of the analytical method to be used. Clearly, since accuracy is limited, producing emissions estimates on a fine grid (say 1 km) for 20 years into the future is not likely to be meaningful. In fact, the grid size, assuming that the chosen air quality analysis method requires a grid at all, should be rather large, say 5 to 10 km, to avoid unnecessarily precise manipulations of rather coarse data. One should be careful, however, not to use a grid so large that important topogrpahic effects are lost through spatial averaging. An additional consideration that enters into the analysis is that facility and operational plans are more specific in terms of their impact on emissions than are either land use or policy plans. Therefore, the selection of grid size should account for the degree of detail of the transportation plans under consideration.

c. Accuracy of Forecasts

The question of accuracy of an emissions inventory is of great importance because the results of the air quality analysis will in most cases be sensitive to errors in emissions. Since emissions inventories cannot be validated (there is no way to collect actual data on vehicular and area-distributed emissions), they are based on random samples of vehicles, relatively sparse traffic counts, and assumptions about the distribution of other sources. It is probably possible to estimate a current regional total within about 50 to 100 percent (an educated guess) considering inaccuracies in transportation models and emissions factors, but any realistic estimate of the accuracy of a 20-year projection is nearly inconceivable. Legal requirements dictate that it is necessary to determine whether a proposed planning decision is consistent with

specific air quality standards; however, in many cases even this cannot be done with confidence. What the air quality analysis does provide in these cases is an indication of the probability of violating National Amtient Air Quality Standards under various assumed land use alternatives. Thus, the question actually being answered is: If the proposed strategy has the effects assumed, what air quality will result?

d. Technical Tools

In developing a regional emissions inventory for a future year, one must consider the variation in population distribution, changes in the split between various modes of transportation, changes in the highway network, and changes in vehicular emissions factors. In many cities, transportation models have been developed that can be used to determine travel demands, modal splits, traffic assignments, and resultant emissions. These models provide an acceptable solution to the problem of projecting growth and future transportation usage and should be used, if possible. EPA estimates of future emissions factors, available in Document AP-42 and its periodic supplements [5], should be used also. Integration of these sources of information should permit the best possible projections of emissions. These issues are discussed in further detail in Chapter III of Volume I of this report.

B. AVAILABILITY OF AMBIENT AIR QUALITY DATA

Characterization of existing ambient air pollutant concentrations can draw upon several data sources. Pursuant to The Clean Air Act Amendments of 1970, the states, through their State Implementation Plans (SIPs), established networks to monitor, compile, and analyze data on ambient air quality and to make these data available to the public upon request. The minimum number of monitors, the pollutants to be measured, and guidelines for monitor siting were also prescribed. These data are readily available through state or local air pollution control agencies at nominal cost. Some regions, particularly where air pollution problems are severe, have augmented the required network with additional monitors operated either on a permanent or limited term (e.g., episodes, special field programs) basis.

With the increase in the number of projects over the last several years requiring some form of environmental impact study or report, a concomitant increase in air quality monitoring studies has occurred. Sponsored by private industry, educational institutions, governmental agencies, or various combinations of each, short and long term special studies have been carried out in some areas. If such studies have been performed in the area of interest to highway planners, they present a potential source of information for use in characterizing air quality levels. Of course, some difficulties may be encountered, such as:

> "Nonrepresentativeness" of particular monitoring sites due to close proximity to strong emissions sources.
> Uncertainties as to which, if any, studies have been carried out.
> Narrowness of the scope of some studies.
> Inaccessibility of some data due to proprietary constraints.
> Unknown quality control/quality assurance of data collection.

C. AVAILABILITY OF METEOROLOGICAL DATA

Meteorological data frequently needed in regional and subregional analyses fall into four categories: winds, atmospheric stability, temperature, and sunlight. Each is discussed briefly below.

1. Winds

Knowledge of wind patterns, both near the ground and aloft, is vital to a successful air quality analysis. As with concentration measurements, general sources can provide surface wind information. First, many air monitoring stations routinely report wind speed and direction on an hourly basis. National Weather Service (NWS) stations, often located at airports, report hourly surface winds, but these are usually available summarized in the form

of three-hour averages. Universities and colleges occasionally record weather data as well. Fire departments, airports, and forestry offices frequently record wind information, but these measurements are generally of limited value because they are normally obtained only a few times a day and are instantaneous values rather than hourly averages.

Upper level wind data (derived from rawinsondes, radiosondes, or pibal soundings) are collected less frequently than surface wind observations. The National Weather Service releases rawinsondes at midnight and noon GMT at about 70 locations throughout the United States to measure winds, temperature, pressure, and humidity in the upper air. In addition to these, about about 80 other stations measure winds aloft four times daily (12:00 and 6:00 a.m. and 12:00 and 6:00 p.m. GMT) using only pilot balloons (pibals). Including certain other upper air stations, the locations in the upper air observational network in the contiguous United States number about 150.

Because wind data are available from a wide variety of sources, the adequacy of data obtained from each must be considered. In some instances, the monitor may be located on a high tower out of the influence of other local topographic influences, thereby providing wind data representative of a rather large region. In contrast, a monitor placed on a shorter building in the lee of tall structures or perhaps elevated terrain features might become dominated by local microscale effects under some wind conditions. In this case, the monitor would not be representative of a large area, and monitoring data would be of questionable utility in an air quality analysis. Finally, because the accuracy and precision of wind sensors vary as a result of many factors (e.g., age, calibration, maintenance, exposure to harsh weather), care must be exercised in the use of wind data (or other data for that matter) obtained from various agencies and persons.

2. Atmospheric Stability

The vertical variation of temperature in the atmosphere, which determines atmospheric stability, affects the impact of emissions on air quality because stable atmospheric conditions (e.g., temperature inversions) limit the

extent of vertical mixing of pollutants and lead to high ground-level concentrations. The main source of information on atmospheric stability in the United States is the rawinsonde or radiosonde measurements discussed above. These data are readily available from the NWS National Climatic Center in Asheville, North Carolina. An additional source of stability data, though not nearly as extensive as the NWS network, is state and local air pollution control agencies. In some of the large cities, agencies maintain additional radiosonde stations and even use daily aircraft spirals and acoustic soundings to provide supplemental data on the occurrence of temperature inversions. Unlike surface wind measurements, which are relatively numerous in metropolitan areas, the availability of data for upper level winds and atmospheric stability is quite limited. It is unlikely that transportation planners will have data from more than one upper air sounding station available when carrying out subregional analyses.

In cases where upper air data are not available, highway planners can still obtain estimates of atmospheric stability based on the simple method outlined by Turner [7]. Using only routinely collected data, such as surface wind speed, radiation intensity, and percentage of cloud cover, Turner proposed a table from which atmospheric stability can be estimated according to one of six categories.

3. Temperature

Surface temperature measurements are valuable in air quality impact analysis because they can be used to:

- Provide additional means for estimating the spatial and temporal variations in temperature inversions.
- Assist in the derivation of statistical relationships involving meteorological parameters and expected air quality.

- > Examine the extent to which emissions rates of CO, hydrocarbons (HC), and NO_x from mobile sources vary with the ambient temperature.
- > Influence, to some extent, the rate at which some secondary pollutants form in the atmosphere.

Surface temperature measurements, often one-hour averages, are generally available from the same state and local agencies that record wind and air quality data.

4. Sunlight

Sunlight (solar radiation or insolation) measurements are important in some subregional analyses, especially when secondary pollutants such as ozone are of concern. Sunlight strongly governs ozone formation. Radiation measurements, though certainly not extensive in number, are obtained in many cities and are available from air pollution control agencies. If radiation measurements are unavailable in a particular analysis, the radiation levels can be estimated fairly well on the basis of time of year, latitude, the extent of cloud cover (recorded every hour by the National Weather Service), and some theoretical considerations.

D. AIR QUALITY ANALYSIS METHODS

Several different types of air quality analysis methods are currently available. They differ in:

- > Spatial and temporal resolution
- > Data requirements
- > Facilities, funding, and training required for application
- > Type and accuracy of prediction
- > Underlying concepts
- > Treatment of atmospheric chemistry
- > Treatment of transport and diffusion.

This section describes how the data resources discussed earlier can be used to estimate the relationship between projected traffic emissions and anticipated air quality. Basically, the planner must select from among several techniques or models the one best suited to the particular analysis at hand. This section provides an overview of the various air quality models available to highway planners; Chapters IV and V offer suggestions as to how one might make this selection for studies of particular types of areas. Air quality models are discussed in detail in Chapter IX of Volume I.

Mathematical quality models can be divided into two generic classes: statistical and deterministic. Statistical models are developed by empirically relating a large number of observations (such as wind speed, temperature, emissions, and ozone concentration) and attempting to uncover what, if any, mathematical relationship exists among them. In contrast, deterministic models are based on mathematical representations of physical and chemical atmospheric processes, as embodied in fundamental laws. Deterministic models vary widely in their degree of completeness in the treatment of atmospheric processes. On the one hand, some models strive to represent many processes in fine detail at the expense of becoming complex and costly to use. On the other hand, simple deterministic models sacrifice accuracy and level of detail in the treatment of chemistry and physics in favor of greater ease of application and lower cost of operation. Both types--simple and complex--are valuable tools to planners, but it is imperative that they be used properly and that their limitations be understood.

1. Statistical Models

Statistical air quality models are undoubtedly the simplest and easiest to use. They do not include spatial or temporal resolution, they do not require detailed emissions data or any meteorological data, and they can be applied quickly without special training or computer facilities. Consider, for example, linear rollback methods. The premise behind this model is that ambient pollutant concentrations are proportional to current emissions levels.

Future concentrations of a particular pollutant can thus be determined from estimates or measurements of current and future emissions and current pollutant concentrations. In some cases, this concept provides acceptable concentration estimates, but for most subregional applications its use is severely limited. So-called modified rollback models for oxidant attempt to characterize the nonlinear relationship between oxidant precursors (NO, NO_2, and reactive hydrocarbons) by employing the basic rollback technique. Various modified rollback models have been proposed, the most familiar of which is the so-called Appendix J relationship recommended in the past by the EPA. (Heretofore, the Appendix J relationship has been used for relating emissions to ambient air quality; however, the EPA has abandoned this approach in favor of others [8], as discussed later). Other types of statistical models are based on time series analyses and multivariate discriminant analysis, but these models have not been developed to the point where they are generally applicable in transportation planning problems.

Because these methods assume a simple curvilinear relationship between emissions and resultant pollutant concentrations, they require only regional emissions totals, regional air quality measurements, and an estimate of background levels at a minimum of one site for their application. The output is presented in terms of a percentage reduction in emissions required for compliance with the standard. Since these methods cannot be tested adequately, their accuracy has not been established on firm theoretical grounds.

Despite the attractiveness of statistical models due to their conceptual simplicity and ease of application, they suffer some limitations that in certain cases render their use in certain planning analyses inappropriate. Specifically, statistical models do not:

- Account for the effects of spatial or temporal changes in emissions.
- Explicitly consider meteorological factors.
- Account for the effects of changing background pollutant concentrations.
- Reflect the influence of changes in hydrocarbon reactivity on oxidant production.

2. Deterministic Models

Deterministic models attempt to relate explicitly emissions to air quality on the basis of fundamental laws of chemistry and physics. Included in this category are systems of equations that simulate processes taking place in a smog chamber as a surrogate for the real atmosphere. This approach is roughly equivalent to treating the region as a box, considering the chemistry in detail, but treating emissions and transport crudely. Although a computer is required for the development of the system, the set of equations can be used to generate a series of charts that can then be used independently.

Numerous models in this class have been developed in recent years to address a variety of air quality concerns, some of which are listed below:

> The formation rate of secondary pollutants, such as ozone and NO_2 (and in some instances possibly even sulfate), in the atmosphere.
> The dispersion and decay of primary pollutants downwind of point, line, and area emissions sources.
> The chemistry and dispersion of reactive materials emitted from elevated point sources, such as power plant stacks.
> The fate of pollutant emissions as they are carried downwind.
> The three-dimensional description of smog formation in an urban airshed.
> The overall characterization of urban air quality, considering the airshed as a single, large parcel of air.

Examples of deterministic models that might be considered for use in transportation analyses are presented in the following subsections. The reader is referred to Chapter IV of Volume I for a more thorough description of the basic model concepts.

a. Isopleth Techniques

One of the important concerns in urban air quality studies is the relationship between the amounts of nitrogen oxides and hydrocarbons emitted during the morning rush hour and the maximum oxidant produced later in the day. Photochemical kinetic mechanisms have been successfully used in conjunction with laboratory smog chamber data to develop so-called ozone isopleth diagrams. These mechanisms are basically sets of chemical reactions expressed in mathematical terms and solved by computer. The chemical reactions attempt to describe the interactions in the atmosphere between various pollutants such as NO, NO_2, ozone (O_3), hydrocarbons, and carbon monoxide (CO). If one can estimate the concentrations of various pollutants in the air at a particular time, then the photochemical kinetic mechanism can be used to predict the concentrations of pollutants at various times thereafter. Figure 3 presents an example of an oxidant isopleth diagram derived through the use of a computerized kinetic mechanism. Given data on concentrations of NO_x and reactive hydrocarbons in the air during the morning, it is possible to obtain directly from the diagram the maximum oxidant that would be formed in the afternoon. Thus, the isopleth technique is quite easy to use.

In searching for a technique to replace the Appendix J relationship, the EPA has recommended an isopleth method called the Empirical Kinetic Mechanism Approach (EKMA) in its interim guidelines [9]. Two types of ispoleth methods appear to be destined for use in revising State Implementation Plans. One is the isopleth method described above. The second, which is more sophisticated, is actually a series of isopleths based on a group of computer runs. For each simulation, various amounts of new emissions are introduced into the hypothetical air volume, dilution of the pollutants is carried out to simulate the rise of the inversion, and the solar radiation is varied. For each set of conditions, an isopleth is produced. The user then selects the isopleth whose continuous emissions, dilution rate, radiation levels, and other factors most closely correspond to those of the area of concern.

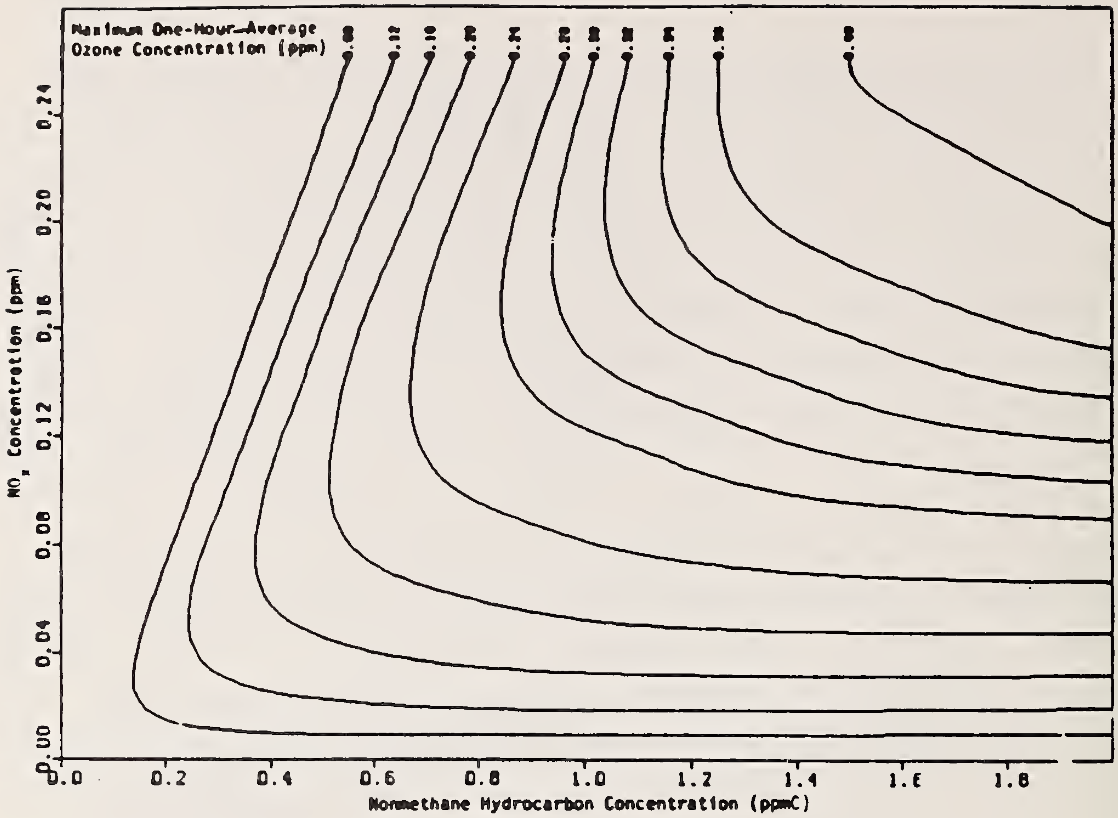


FIGURE 3. SAMPLE OZONE ISOPLETH DIAGRAM DEVELOPED FROM A PHOTOCHEMICAL KINETIC MECHANISM

As discussed in Volume I, isopleth techniques have several advantages and shortcomings. For example, once an isopleth is developed, various control strategies can be examined without the use of a computer. The development of isopleths also embodies many of the nonlinear chemical processes that occur in the atmosphere. The shortcomings of this approach include the inability to test the absolute predictive accuracy of the isopleths because such tests require the imposition of emissions control and a long (e.g., three or four year) waiting period before the effect of the controls can be ascertained. Moreover, the method does not account for spatial redistribution of emissions patterns or changes in hydrocarbon reactivity over the years.

The validity of the EKMA can be examined only in a limited way by studying the relationships of HC, NO_x, and oxidant concentrations in various urban areas. However, at this point even this type of testing has been limited. The accuracy of the EKMA is considered superior to that of statistical methods, though quantitative results from various regions are difficult to obtain because of the lack of data, differences in meteorology and topography from one region to the next, and variations in the mix of hydrocarbon species emitted in different areas.

b. <u>Algebraic Models</u>

Algebraic models, of which the Gaussian model is the most familiar, are based on an extremely simplified form of the mathematical equation that describes the transport, diffusion, and reaction of pollutants in the atmosphere. These models have been used to study the fate of roadway emissions, point source emissions, and the dispersion of pollutants from area sources. For a single point or line source, the models are very easy to use, requiring only a few charts or graphs and a hand calculator. For multiple point sources or numerous interconnected line sources, it is often convenient to computerize the model equation, thereby avoiding tedious calculations.

With suitable inputs such as emissions rates, wind speeds, and sunshine, algebraic models can be used to estimate pollutant concentrations on the ground and aloft downwind of the source. Because the model is "steady state," one must operate the model successively to obtain the time variation in pollutant concentrations due to varying meteorological or emissions conditions. Algebraic models do not treat the disappearance of primary pollutants and subsequent formation of secondary pollutants (such as ozone), though they can be used to estimate the rate of decay of linearly reactive pollutants.

Certain assumptions made in the formulation of the Gaussian model concept make it relatively easy to use but at the same time restrict the range of conditions over which the model is a useful analysis tool. In general, this model

concept is best suited for flat terrain applications under uniform wind and mixing conditions for short (e.g., one-hour) time periods. The reader is referred to Volume I for a more complete discussion of the model's assumptions and limitations.

c. Trajectory Models

Trajectory models are based on the concept of a moving air parcel within which pollutants react. As the hypothetical parcel moves across an area with the wind, pollutants enter the parcel from the bottom (ground-based emissions) or at some intermediate level between the ground and the inversion (elevated emissions). Trajectory models are mathematically more complicated than algebraic models, primarily because the equations describing the various photochemical reactions are both numerous and nonlinear. Thus, a computer is necessary to operate trajectory models.

Because pollutant concentrations are calculated only within the volume of the moving air parcel, it is necessary to operate the model several times, beginning at different times of the day, to determine the variation in pollutant concentrations at a particular point in a city throughout the day. This class of models can often be used to estimate the impact of roadway emissions on the formation of ozone and NO_2 downwind. Although they do require the use of a computer, the cost of one simulation (assuming the data have already been prepared) is typically less than $10. Of course, to assess a particular emissions control strategy, one may have to run a number of simulations with a trajectory model; if so, computational costs would be much greater. Trajectory models appear to be suited to applications for which the emissions source distribution are relatively homogeneous (spatially) and for meteorological conditions under which pronounced wind shear in either height or direction do not occur.

d. Box Models

Box models consider a single, stationary cell. All variables are averaged over the cell volume. Although spatial resolution is not provided, box

models do permit study of the temporal variations in primary or secondary pollutant concentrations. The lack of spatial resolution prohibits use of this type of model to investigate air quality impacts at specific places within a subregion, but they can be used to investigate overall urban air pollution levels, particularly if the emissions distribution is reasonably homogeneous. Box models must be solved by computer, but the expense is minimal, roughly equivalent with that of trajectory models. The results from box model simulations are curves describing the temporal variation of the concentration of each pollutant.

e. Grid Models

Grid models represent the most sophisticated class of air quality models developed to date. These models are based on a stationary two- or three-dimensional array of grid cells, within which pollutants are emitted, transported from cell to cell, diffused by turbulence, chemically transformed, and removed from the grid region by rain, adsorption on the ground, and other means. A computer is required to apply such models, as are specially trained personnel. The required input includes a time-varying grid-based emissions inventory, spatially resolved time-varying and inversion height data on wind, insolation, initial conditions, and background concentrations. The output is in the form of time-dependent concentrations of each pollutant in each grid square. Summary statistics, such as mean, maximum, number of violations, and dosage rates, may also be provided.

As a class, grid models provide the highest level of detail in the treatment of relevant atmospheric processes. Because concentration predictions are available for numerous locations (both at the ground and aloft), these models are well suited to the analysis of regional and subregional impacts due to variations in emissions rates or locations of sources. Concomitant with the complexity and sophistication of grid-based photochemical models are large computing and data base requirements. The computing demands of some of the newer models may nearly exceed the capabilities of even the

largest machines. Computing costs for an urban area such as Los Angeles, California, may run as high as $1000 to $2000 for a 24-hour simulation. Preparing an adequate data base for these models may cost anywhere from $10,000 to $100,000 depending on the availability of data and skilled personnel. Finally, the amount of output information available from these complex models is very large, and often statistical methods are needed to interpret the model's output.

3. Comparison of Models

Because the output from grid models can be compared with measurements (more or less directly), the models have been subject to preliminary validation. Of the candidate approaches, it appears that this class of methods is the most accurate, with estimates of pollutant concentrations usually within 50 percent. (A more detailed discussion of model accuracy appears in Volume I.) The main distinctions among the various classes of models are summarized below:

- > Statistical methods
  - Simple application
  - Prediction of the required level of emissions control
  - Absence of spatial and temporal resolution
  - Limited data requirement
  - Theoretically weak foundation
  - Untestability.
- > Deterministic methods
  - Relatively simple application
  - Prediction of maximum concentrations
  - Absence of spatial and temporal resolution
  - Modest data requirement
  - Limited technical basis
  - Limited testing of validity.

> Grid-based models
  - Complex application
  - Prediction of time- and space-varying concentrations
  - Full spatial and temporal resolution
  - Extensive data requirement
  - Solid technical basis
  - Testable validity.

In the description of models, no attempt was made to evaluate the relative superiority of the concepts; rather, those situations for which the models are best suited were identified. Many factors enter into selection of the best model. From a purely technical standpoint, the choices are fairly straightforward. Where spatial and temporal resolution are required, the grid models are the only choice. If spatial resolution is not required and if secondary pollutants are involved, the deterministic class is the appropriate choice, though grid methods can be employed if greater accuracy is desired. In cases where primary or secondary species are involved and spatial resolution is not required and no spatially stratified emissions data and meteorological data are available, rollback methods can be used. In cases where evaluation of the regional impact of primary pollutants is desired, grid approaches can be used because of their greater accuracy compared with rollback methods. Of course, the availability of data, funds, facilities, and personnel is an important constraint that may render some approaches infeasible.

Because the selection of the proper modeling approach for a particular problem may at times appear to be perplexing, highway planners may benefit from consultation with personnel in the appropriate EPA regional office. The EPA is engaged in an ongoing program to standardize the model selection and application process. In addition to continuing efforts to upgrade existing models and to support the development and validation of new models, the EPA is sponsoring work aimed at developing measures for assessing model performance and procedures for determining these measures. Although one normally does not encounter difficulty in interpreting the

results of simple algebraic models, interpretation of results obtained for an analysis area by a more complex model is often quite complicated. The EPA-sponsored studies should provide assistance in selecting the most appropriate models and in interpreting their results.

E. INTERPRETATION OF MODELING RESULTS

Once the output of a model has been obtained, the results must be interpreted with respect to the transportation planning issues to be evaluated. These issues may include compliance with air quality standards, prevention of significant deterioration (PSD) requirements, and possibly State Implementation Plans. In comparing model results with legal requirements, one must consider the form of the model's predictions and its resolution and accuracy.

1. Air Quality Standards

Air quality standards are set by both the federal government and the individual states; where there are two applicable standards, both must be met. The federal standards are ordinarily presented in the form of a specified averaged concentration that is not to be exceeded more than once per year at any location; state standards may differ. Although their wording is clear, air quality standards are open to complex and at time controversial mathematical and physical interpretation. In addition, the PSD requirements must be met; specific details of those requirements have not yet been promulgated. To evaluate compliance with standards and PSD requirements, one must resolve several issues, including the analytical methods to be used, the appropriateness of comparing spatial averages with point measurements, the siting of monitoring equipment, and the procedures for statistical analysis of air quality and meteorological variables. The EPA offers specific guidance on the accepted practice in each of these areas [9-14].

In the strictest sense, ambient air quality standards are not to be violated anywhere at ground level. Thus, to determine whether the CO standard was being violated, one might place a monitor near the median of a heavily congested roadway, or perhaps between two lanes of traffic. In

practice, however, the siting of air quality monitors is governed by certain objectives set forth by the EPA in attempting to achieve the major goal of The Clean Air Act, i.e., the protection of human health and welfare. Specifically, three categories of monitoring sites have been defined (peak, neighborhood, and background), each with a different purpose. A peak site should be located at a point where the highest pollutant concentrations and exposures are expected to occur. Neighborhood sites are used to characterize broad areas of reasonably uniform land use. Background sites are used to measure the concentrations of pollutants that are transported into the region of interest.

The EPA offers guidance in the siting of monitors for each criteria pollutant. Four types of sites for CO monitoring have been identified:

- Street canyons
- Neighborhoods
- Corridors
- Background.

The street canyon and corridor sites fall into the "peak" category mentioned above. The overall goal of the CO monitoring network is to typify population exposures under a variety of conditions, including peak (one-hour) and average (eight-hour) periods. The recommended locations for oxidant monitors differ from those for CO because oxidants are secondary pollutants. Peak monitoring sites for oxidant are typically 15 to 25 km downwind of major source regions because of the time required for oxidants to form.

In its interpretation of The Clean Air Act and in proffering guidelines for the design of monitoring networks, the EPA has made it possible for highway planners to identify typical (though by no means all) locations at which compliance with air quality standards might be assessed. For CO, as an example, sites where people could be exposed to high CO concentrations for one hour or more include sidewalks, parking lots, and downtown office buildings, or homes adjacent to highway right-of-ways. For oxidant, the important sites would be those toward the downwind edge of the region, removed from the immediate vicinity of strong sources of NO.

2. Assessing Compliance with NAAQS

Determining whether a proposed transportation policy or plan will result in compliance with standards requires a predictive tool relating projected emissions to the pollutant concentrations that would occur as a result of those emissions. In general, concentrations should be estimated for the smallest spatial average that is consistent with available data and analytical tools and computational facilities, for example, each square in a modeling grid. If for some reason a technique must be used that yields predictors for specific locations only, then the predictions should, at a minimum, be made for sites that are currently monitored to validate the air quality model; predictions should also be made for the most adverse site. This practice facilitates the use of monitoring data in establishing baselines and validating predictive methods, and it is consistent with the current approach to evaluating air quality.

The predictions should allow direct comparison to air quality standards in terms of averaging time. For example, CO predictions should be made for both 1- and 8-hour averages for comparison with federal standards and for other averages as well if required by the states, such as 12-hour averages in California; most of the models have this capability. Specific procedures to account for overlapping exceedances are discussed by Curran and Hunt [10]. Also, the predictions should be made for meteorological and source conditions that lead to the expected (in the statistical sense) second-highest value for a given calendar year.

A problem arises in comparing model predictions with air quality standards because different models produce different types of predictions, such as:

> The number of exceedances at a point in space.
> Maximum concentrations at a point in space.
> Maximum concentrations averaged over a grid volume.
> Maximum concentrations averaged over the entire region.
> Level of reduction in emissions required for compliance with the standards.

Each of these forms may apply either for an entire year or for a specific episode, depending on the type of model used. In the former case, comparison with standards is straightforward, whereas in the latter, additional assumptions are required.

For comparison of the output of an episode-type model with standards, a good approach is to use data representative of meteorological conditions on a day when the second-highest value was recorded in a previous year. The model is then run using those conditions as input, and the highest predicted concentration is used for comparison with standards. Sometimes sufficient meteorological data will be available only for certain episode conditions. Such data may be best applied for determining the effects of control strategies during episode conditions; direct comparison with standards is of uncertain accuracy because the meteorological conditions are not necessarily representative of the second-worst case.

3. Model Sensitivity

The basic question of model sensitivity centers on evaluating the capability of available analytical procedures to produce statistically meaningful estimates of the effects of a proposal. For example, a 1 percent increase in traffic levels on an urban freeway does in fact produce an increase in emissions and, therefore, higher concentrations of pollutants. However, the procedures for estimating emissions are probably not accurate within less than 10 percent at best (in fact, 50 or 100 percent is more common), and the procedures or models used to estimate concentrations from these emissions are also unlikely to be accurate to within less than 10 percent. Consequently, the prediction of concentrations due to a 1 percent increase in traffic is beyond the statistical significance capability of the current state of the art of air pollution analysis.

In current practice, this problem is usually treated by making conservative assumptions about emissions, by using "worst-case" meteorology, and then by accepting the predicted concentrations without further

consideration of errors. For a statistically unbiased model, this practice leads to equal probabilities of the predictions being higher or lower than actual values. Because the models are probably more accurate at predicting differences in concentrations resulting from alternative proposals than absolute values, they may be more useful in determining whether a proposal complies with nondegradation requirements--for which detection of differences is the desired result--than for determining compliance with air quality standards.

4. Presentation of Modeling Results

Effective communication of the modeling results is especially important because of the varying extent of technical understanding of those who will read the air quality report. Typically, the findings of the study may be embodied in an environmental impact report, they may form the basis for decision-making, and they may be used in discussions at public hearings, often by people who did not participate in the study. Accordingly, it is necessary that the report address several levels of understanding, yet at the same time enable a full understanding of the study's findings by nontechnical persons.

Several data analysis techniques are available to aid in the task of interpretation, including bar charts, correlation graphs, graphs relating more than two variables, log or semi-log plots, nomograms, probabilistic plots, and probability distributions. Regardless of the analysis techniques used, however, certain items should be presented:

> Ambient air quality data, both during the base case (the present time) and throughout the expected lifetime of the project.
> The pollutant burden from the present to some future time (say, ETC + 20 years) that would arise as a result of the project.
> Pollutant trends, both short term (such as those related to 1-, 8-, or 24-hour averages) and long term (seasonal and annual). These can be obtained directly from the model output or through

application of Larsen's methods [11].

> Estimates of the frequency of occurrence of worst-case meteorological conditions and the distribution of pollutant concentrations to be expected during such conditions.

> Expected number of exceedances of air quality standards at ETC and ETC + 20.

Finally, the report should identify, where possible, major assumptions in the analysis and possible sources of uncertainty and inaccuracy, and it should estimate the degree of accuracy of the analysis. In so doing, model users will enable the quality and soundness of the analysis to be readily evaluated by others who may use the study results as a basis for decision-making.

5. EPA Guidance on Model Usage

The EPA's "Interim Guideline on Air Quality Models" [9] prescribes ways for using the various types of output of the recommended models and for comparing results with standards. That guideline also considers the selection of meteorological data leading to assumed worst-case concentrations, which are used as a proxy for second-highest values. Further development of procedures for the application of models is the subject of ongoing EPA research [15].

IV REGIONAL-LEVEL PLANNING

This chapter describes the air quality and transportation relationships important to regional-level transportation planning. Section A discusses the overall regional context, defining what is meant by a region, outlining the type of transportation problems and decisions that are encountered, and presenting the related air quality considerations. Subsequent sections address each of the types of air quality considerations individually (land use, transportation policies, operational and facility plans), giving guidelines for incorporating them into the analysis process.

A. DEFINITION AND DESCRIPTION OF REGIONAL-LEVEL PLANNING

In the context of this manual, the urbanization pattern of an area is the key feature in defining a region, which is a generally contiguous urban area with considerable interdependence between its different portions in a planning and transportation sense. Variations in air quality will occur throughout a region, but few portions will be independent to the extent of experiencing completely isolated air quality situations. Topography is important if it influences the urbanization pattern and if it suggests natural limits for the air quality analysis. Examples of regions include the greater New York metropolitan area, the Los Angeles area (in particular, portions defined as the South Coast Air Basin), and Chicago and its suburbs.

A region is not the largest area designation within which transportation planning is carried out; state-wide planning encompasses more than a single region, and broader based transportation planning may cover several states or the nation as a whole. However, in considerations of the relationship of air quality to transportation, a region is the appropriate scale at which area-wide analyses are carried out. Use of the term "region" in this context therefore implies certain geographic and jurisdictional characteristics.

1. Jurisdictional Characteristics

A region of the type considered in transportation planning generally has at least one jurisdictional agency, for example:

> Metropolitan planning organizations (MPOs). These are designated by a governor for specific metropolitan regions in the country. They are responsible for various designated planning functions in those regions and generally for controlling the expenditure of certain types of federal funds.

> Council of governments (COG). This organizational framework can take many forms. It is not necessarily different from an MPO since many MPOs are in fact COGs in some form. COGs are generally formed by a joint powers agreement among member agencies defining the function and responsibilities of the COG.

> County planning agency. In some cases, when a county meets the definition of a region, the County Planning Department acts as a regional planning agency, providing a coordinated planning function for all jurisdictions within the county.

> City planning agency. In a few cases, an individual city is large enough to be considered a region. In general, however, an urban area extends into the surrounding county or counties, and the city itself is then a subregion rather than a region.

> Special regional agencies. Special regional agencies exist for specific purposes (e.g., utilities, air quality). Those with responsibility for transportation are generally established by state legislation, and they have control of state and federal funds for transportation purposes.

In the definition of a region, therefore, the type of jurisdictional organization is of less importance than the powers and responsibilities held. The organization may or may not be an implementing agency, but it generally sets the regional land use and transportation policies that the implementing agencies follow. It may also have considerable voice in the expenditure of transportation funds.

As the above discussion implies, there is considerable variation from area to area in the relationships between a region and the surrounding jurisdictions (county, adjoining region, state). In most cases, the legislation or agreement creating the regional agency defines these relationships. In general, the regional agency is a level of government between (1) the relevant state or federal agencies and (2) the jurisdictions contained within the region (cities and counties). In an organizational sense, therefore, external jurisdictions are those higher level agencies with which the region must coordinate for one reason or another.

In a heavily populated and industrialized area, such as the northeastern states, emissions in one urban area may have a significant effect on air quality in a downwind urban area. In such cases, air quality planning may need to be carried out by high-level, multijurisdictional agencies. In a technical sense, the term "region" used for air quality impact analysis could be defined to include more than one urban area. However, this type of analysis has not yet been used in air quality planning practice for two main reasons: (1) the lack of proof that more stringent air quality controls are needed to prevent violations of standards downwind of a region than are already required to prevent violations within the region, and (2) legal problems in setting up the administrative structure required for instituting controls at this level. One of the key features of a region as defined here is its multijurisdictional nature. Since regions are largely defined by their pattern of urbanization, they inevitably encompass several jurisdictions (such as cities and counties). The interaction

between different jurisdictions creates the need for many planning decisions to be made in a regional (and therefore multijurisdictional) context.

2. The Difference Between a Region and a Subregion

While the difference between a region and a subregion includes both geographic and jurisdictional characteristics, in the context of air quality analysis the geographic differences and the pattern of urbanization are the most important. Apart from the localized "hot spot" phenomenon, air quality is a function of area-wide emissions levels and the geographic and meteorological characteristics of the air basin in which these emissions occur. Air quality will differ throughout an air basin, but the air quality in any particular locality depends on occurrences within that locality and in the area upwind. The difference between a region and a subregion is therefore largely the extent to which the air quality in the area under consideration is affected by the surrounding area. A subregion is significantly affected by anthropogenic sources in surrounding areas, whereas a region is not. In other words, a region usually includes an entire developed area, whereas a subregion is usually a smaller area within a region.

3. Types of Transportation Planning Problems and Decisions

For the purposes of the guidelines given here, the specific transportation problem and decision areas requiring analysis at the regional level are divided into three groups:

> Land use
> Transportation policies
> Facility and operational plans.

Separation of the regional problem into these three groups does not imply independence among them. Development of a comprehensive transportation plan, for example, involves all three. However, certain differences occur in the treatment of planning problems in each of these areas, largely in

terms of the accuracy and detail of the emissions inventory. The analysis procedure selected depends on which of the three, or which combination, is to be analyzed.

The following discussion briefly describes these three areas of concern. More detailed discussions of each are given later in this chapter when the corresponding air quality analysis aspects are also described.

a. Land Use

The geographic distribution of population and employment is the basic determinant of travel patterns and hence of emissions. Land use decisions must be assessed in relation to their transportation impacts as well as the various other considerations involved.

Typical examples of the types of regional-level land use decisions that affect transportation (and hence require transportation analysis) are those concerning:

> Amount of growth (population forecasts).
> Pattern of residential growth.
> Location and intensity of employment.
> Location and intensity of industrial and commercial land use.
> Open space.
> Residential density.
> Commercial density.

The two primary issues are the amount of growth (or more appropriately, rate of growth) and the pattern or distribution of growth. These issues must be addressed at a regional level to establish an overall regional planning framework for dealing with more detailed local considerations.

b. Transportation Policies

As a general rule, regional jurisdictions are planning entities, and in many cases they have no implementation responsibilities. Regional policies are important in transportation planning when they affect the amount, pattern, or modal content of travel. In this context, typical subject areas that are considered include:

> Accessibility and mobility
> Air quality
> Energy conservation
> Resources allocation (funding)
> Organizational framework for implementation.

Although land use policies also require consideration with the above, they are more appropriately dealt with under land use because their effect on transportation is indirect rather than direct.

c. Facility and Operational Plans

This decision category has the most direct effect on traffic and hence on emissions, since these plans determine where and how traffic will move and other key factors. Such plans are necessarily dependent on the land use plans and transportation policies for the region. Transportation plans are designed to serve the land use pattern, and transportation policies provide guidance as to how the plan should endeavor to serve the land use pattern. Within that framework, actual implementation is carried out by means of facility and operational plans.

For this category, the decisions being analyzed consist of proposals for actual physical design and operation of transportation facilities. These include new facilities, improvements to existing facilities, operational changes, or a combination of these types of improvements. The planning is

necessarily more specific and more concerned with physical facilities than is policy analysis. However, despite the greater specificity, facility and operational plans at the regional level may not be able to provide sufficient detail for implementation decisions. Subregional planning is often the mechanism that carries the planning process one step further, concentrating on a finer level of detail and developing detailed plans for implementation.

B. AIR QUALITY ANALYSIS AT THE REGIONAL LEVEL

The primary question to which all air quality analyses are directed is: Under what circumstances will air quality requirements be violated and to what extent? As described in Chapter III, various types of air quality models can be used to evaluate transportation plans. In this section, the application of those methods to regional air quality analysis is described. The issues that must be considered in selecting an appropriate air quality model for a particular regional analysis include:

> Which pollutants are to be treated.
> The nature of the transportation plan under consideration.
> Specific legal requirements regarding air quality.
- NAAQS
- PSD requirements
- State standards
- State Implementation Plan requirements.

> Characteristic air pollution problems of the region.
> Availability and preparation of input data.
> The desired level of model resolution and type of output.
> Model validation and financial, computational, and personnel resources.

1. Pollutants To Be Treated

As noted in Chapter III, different modeling techniques treat different pollutants. On the regional scale, hydrocarbons, nitrogen oxides, and

oxidants are ordinarily treated. Occasionally, large shifts in projected CO emissions may require that a regional model be used to provide background concentrations for input to corridor-level CO analyses. Levels of other pollutants, such as sulfur oxides, particulates, and "minor" contaminants, are usually not significantly affected by motor vehicle use at the regional level. However, if transportation plans indirectly affect sources of these pollutants, then these sources must be evaluated.

2. The Transportation Plan

The nature of the transportation plan under consideration has its greatest impact on the selection of the appropriate level of spatial resolution, which in turn is an important factor in selecting a model. The principle behind the selection is whether the plan under consideration is likely to cause significant change in the spatial distribution of emissions in the region; the spatial resolution of the air quality model should be commensurate with that both of the problem under consideration and of the available traffic and emissions projections. In addition, the selected spatial resolution for the air quality model must be consistent with that of the transportation models. Since the latter models may already exist, they often determine the maximum spatial resolution of the air quality analysis.

3. Legal Requirements

The specific legal requirements on air quality may consist of limitations on concentrations in accordance with NAAQS, state standards, or PSD requirements, or limitations on emissions rates in accordance with State Implementation Plans. Most of the modeling approaches discussed in Chapter III have been approved by the EPA for use in determining compliance, though some are more accurate than others, particularly when applied to the specific situations for which they were validated. When highway planners must choose a model for a given air quality analysis, they will probably select the

approach best suited to the problem from amongst the EPA-approved alternatives. Note that EPA guidance documents do not necessarily include all available techniques because of the delay between the construction and validation of the model and its approval by the EPA. However, the EPA approves the use of alternative methods, such as photochemical models, if their adequacy can be demonstrated.

4. General Characteristics

The general air quality problems and meteorological characteristics of the region being considered enter the analysis in several ways. Analyses are designed to evaluate legal requirements concerning noncompliance and nondegradation that are based on current air quality. The air quality standards specify a level that is not to be exceeded more than once per year. Therefore, meteorological conditions and source configurations that can be expected to promote such exceedances in the region must be considered. In actuality, procedures for determining the exact conditions of the "second-worst case" are not usually feasible, and so some assumptions are typically made for meterology. These may take the form of assumed worst-case conditions or the use of data collected during an episode for model input. Assumptions of the worst-case conditions for emissions levels are more difficult to construct. The current practice is to use the expected emissions rates for the season in which the worst-case meteorology occurs.

5. Input Data

The various candidate air quality models vary widely in their data requirement. Some require only region-wide emissions rates and rudimentary air quality monitoring; others require a grid-based emissions inventory, substantial meteorological data, and extensive monitoring data for validation. In selecting a model, one must determine whether necessary input data are available or can be obtained from a field program. This investigation will usually require contacting several agencies and carefully

evaluating their data files. Chapter III of this volume and Chapter IX of Volume I describe the required data for the various models.

Emissions inventories must be prepared for each alternative under consideration (including the decision not to build) for the estimated time of completion and for 20 years from then. Intervening years should be included as well if higher emissions levels are likely. Both vehicular and nonvehicular sources should be included in both cases. Inherent in the evaluations are the effects that the plan may have on other types of sources by influencing regional growth, demographics, and transportation patterns.

6. Model Resolution

For regional analyses, the resolution of the selected model should be commensurate with that of the plan to be evaluated and the relevant air quality standards. Since air quality standards, in the strictest sense, apply everywhere, the most desirable prediction is the second-highest value at all points in space. Grid-based models, which may operate on a grid as fine as 1 km, come the closest to this goal, whereas rollback or isopleth models, for example, have no spatial resolution at all. Although models without spatial resolution are currently approved by the EPA for use [9], in most cases it is desirable to have spatial resolution for regional analyses so that important effects are not masked by spatial averaging. However, proposals that do not cause substantial changes in the spatial distribution of emissions for areas having relatively simple topography and meteorological conditions are good candidates for application of non-spatially resolved models.

As noted in Chapter III, temporal resolution is dictated by the relevant air quality standard. Thus, it is necessary to select a model that provides output that can be used to evaluate compliance with standards. Although most models have this capability, some require statistical extrapolation to convert annual average values into extreme values or vice versa. Using a model whose predictions directly include the desired temporal

resolution has a distinct advantage in accuracy over those that require an additional statistical procedure.

7. Type of Output

Various models produce different types of output, as described in Chapter III of this volume and in greater detail in Chapter IX of Volume I. The spatial and temporal resolution of the model are the primary determinants of the type of output. Exceptions include those models that estimate numbers of exceedances of standards or required control rather than predict pollutant concentrations. Each of these types of output is applicable to determining compliance with air quality standards and PSD requirements.

Interest is growing in expressing pollution levels in terms of population dose, which is a measure of the exposure of the average individual to air pollution, and in identifying dose levels at sensitive receptors, such as schools, hospitals, and convalescent homes. Such estimates can be made, but there are no guidelines for acceptability in either case other than those provided by National Ambient Air Quality Standards and PSD requirements. For sensitive receptors, it may be useful to determine whether a violation of standards is occurring at particular sites. For population dose estimates, concentration predictions should be made at a level of resolution compatible with demographic data; this probably requires a grid-based model.

8. Model Validation

Development and validation of an air quality model is a fundamental part of the evaluation process. For some of the simpler models, little or no region-specific evaluation is possible. However, for the more complex approaches, extensive testing and validation are possible and desirable. First, a model must be adapted for use in a particular region, a process that often entails preparation of input files or meteorological, emissions, and topographical data as well as possible modification of the structure of

the model to account for local meteorological and emissions characteristics. The adapted model must then be tested by comparing its predictions with air quality data. Finally, the model must be transferred to the user and applied to the transportation planning problem at hand.

In response to the problems caused by uncertainties in model predictors, the EPA's Office of Air Quality Planning and Standards is currently studying performance standards for the application of air quality prediction methods [15]. This research will establish guidelines to help users judge when a model is performing adequately. The results of this effort should provide further guidance for considering the effects of potential errors in comparisons of air quality predictions with standards. Additional experience with air quality analysis will probably result in improvements in the estimation of the uncertainties associated with predictions. As this occurs, the usefulness of the models will increase. In the interim, the current practice of making realistically conservative assumptions appears to be the appropriate method to follow.

9. Required Resources

A final issue in the selection of models is the wide variation in the complexity and accuracy of the available models and the associated difficulty and expense in applying them (see Chapter III). The statistical-empirical and deterministic-mechanistic approaches may require relatively little data, they do not require extensive training, and they may be applicable with only a few hours of effort using a pocket calculator. However, they are less accurate than the more complex physiochemical approaches, which require far more data and which must be applied by specially trained personnel. The selection of the appropriate model always requires balancing the desired level of technical treatment with the availability of data, funds, computational facilities, personnel, and often calendar time.

10. Conclusions

The logical procedure for air quality analysis in transportation planning is to follow the EPA's guidelines in fulfillment of The Clean Air Act and its amendments as they become available to determine what changes in concentration, if any, will be acceptable. To determine whether a given proposed project must be carefully evaluated for potential significant effects on air quality, one can use the inexpensive analytical methods described in Volume I to screen out projects that show no reasonable probability of violating NAAQS or nondegradation requirements. The definition of "reasonable probability" should be based on the confidence limits of the screening procedure to indicate a small (perhaps 5 to 10 percent) probability of exceeding air quality standards.

C. LAND USE PLANNING DECISIONS

Travel demand arises from the direct interaction between different types and locations of land use. For example, residential areas generate trips that are directed to areas of employment and other activities. The location of residential areas with respect to the employment/activity areas thereby determines this element of the travel demand pattern. To some extent, the transportation system can affect the travel patterns (for example, it may provide a greater ease of travel to one area versus another), but it has only a minor effect on the overall level of demand.

This basic importance of land use as a traffic determinant is reflected in the transportation forecasting process. The transportation model structure depicted in Figure 2 shows how land use data are primary input to the model, which in turn determines the amount of trip generation and then the spatial distribution of these trips. The direct relationship between land use and transportation means that land use decisions have a primary impact on air quality. Decisions about the nature and distribution of land use affect the pattern of travel, which in turn produces the spatial pattern of emissions.

In general, land use planning decisions relate to some future point in time, whether in the near term (e.g., redevelopment programs) or the long term (e.g., 10 to 30 years). Land use decisions that affect transportation are those to convert vacant or low intensity land use to a higher intensity of use. The questions to be addressed are therefore concerned with the type, amount, and pattern of growth, since incremental changes in land use determine the incremental growth in travel. Spatially defining the land use changes enables the corresponding travel changes to be similarly defined.

1. Types of Land Use Decisions That Require Analysis at the Regional Level

Land use planning at the regional level is generally broad in nature because major decisions such as the type, amount, and location of growth cannot be made easily at the subregional level. When these questions are resolved through a suitable regional land use plan, secondary-level decisions such as specific zoning and siting of facilities can be dealt with locally. The regional land use plan thus provides overall direction to ensure that land use is compatible with other aspects of regional planning, such as transportation, air quality, natural resources, and recreation.

a. Amount and Rate of Growth

The amount of growth is of primary concern because it directly relates to the total amount of travel and hence the total amount of emissions. Trends for future growth in a region are thus the basic starting point for analyzing future land use.

State-wide land use planning can affect both the amount and the type of growth in the region. For example, the location of basic industries (a prime determinant of growth rate) may initially be analyzed state-wide to ensure compatibility with specific state-wide planning policies. Since analyses of land use pattern changes are always carried out for some future

point in time, the rate of growth is also an underlying concern in every case. To be meaningful in a transportation (and air quality) sense, the estimated changes must correspond to some projection year, so that there is a known implementation time frame for the corresponding transportation changes (and a specific projection year set of emissions factors).

b. Pattern of Growth

As growth occurs in different parts of a region, incremental, area-specific changes in the regional travel patterns result. These in turn change the spatial emissions pattern of the region. The interaction between transportation and land use influences the demand for growth in a given area. For example, a change in transportation accessibility, such as improvement of the transportation system serving one area, can increase the demand for development in that area. If other factors are equal (e.g., zoning policies, tax assessment), growth will be higher in the area with higher accessibility. Therefore, while land use generates travel demand and thus creates the need to provide transportation facilities, the resulting facilities can in turn affect land use growth.

Some of the specific aspects of the pattern of growth that are addressed at the regional level are:

> Residential density. The number of persons per unit area determines the amount of traffic generated per unit area. It also has implications regarding dwelling unit types (i.e., single-family versus multifamily dwelling) and travel characteristics (such as trip purpose mix).

> Zoning. This is a primary determinant of the spatial distribution of different types of land use; however, it is nonquantitative in the sense that it implies

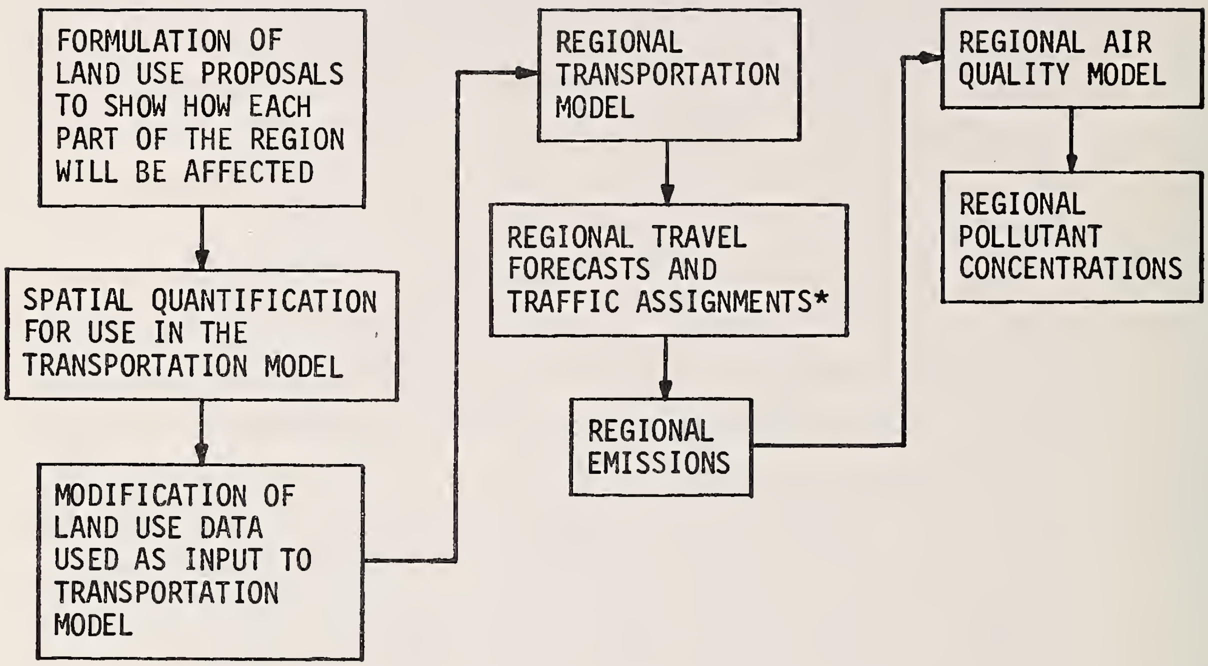
only a maximum amount of activity and does not forecast the amount of activity. (For example, the land could be totally undeveloped in the given time frame, or it could reach its maximum development capacity.)

> Commercial and industrial activity. The location of such activity generally follows from a zoning plan. However, as pointed out above, the actual amount of activity may vary considerably for any locality. The amount and density of commercial activity (and the corresponding density of employment) define the urban activity centers of a region. A highly concentrated and large-scale center, such as a downtown area, will create large travel demands concentrated in a single area, whereas a dispersed pattern of activity will create a more dispersed set of travel demands.

> Open space. Open space also follows directly from zoning plans, which dedicate specific areas to it. However, many areas that do not have open space zoning may remain undeveloped for some time. Until then, they are either open space or lower density areas of development for that particular zoning designation.

2. Required Air Quality Analyses

As shown in Figure 4, the various steps of an air quality analysis of land use decisions follow from the generalized regional transportation planning process described earlier. The actual methodology followed will depend on the availability of data and of models and on other factors. Generally, however, the basic input to the process is the spatial quantification of the land use proposals. These values are converted to travel estimates and then to emissions forecasts. The process is repeated for a future year, usually 20 years hence, including effects on land use induced by the proposal itself.



* Entails a complete run of the transportation model.

FIGURE 4. ANALYSIS OF LAND USE DECISIONS

a. Land Use Planning Models

Although future growth patterns are influenced by various land use decisions, such decisions seldom closely control the differential development rates within the overall planning framework. Most of the many factors that are involved are well understood, but the exact mechanism for actual cause and effect is not. Various types of land use models have been developed to simulate this mechanism by quantifying the distribution and region-wide growth increments for different land use types and by allocating each growth increment geographically [16,17].

The main interest in land use models in this context is in understanding their basic mechanism so that land use plans and decisions can be quantitatively interpreted, particularly in cases where such plans are in the form of broad policy and where the actual quantifications are determined by land use models. The output of the models (adjusted as necessary to reflect the policies more accurately) is a quantitative representation of the land use plan and hence would be an input to the transportation analysis process being discussed here. Some of the factors incorporated in the land use models may affect the type of transportation analysis carried out. For example, if a particular transportation network was assumed in determining accessibilities in the land use model, any departure from this network in the transportation analysis would invalidate the use of the model.

Recent trends suggest that applications of land use models are decreasing, partly because of their inherent shortcomings and partly because of greater land use controls. Projections of future growth tend to be based on a combination of past experience, policy considerations such as those mentioned above, and predicted changes in socioeconomic characteristics (e.g., income, family size, housing densities). Present experience suggests that most regions work with several forecasts covering a range of values for uncertain variables.

The land use forecasting aspect of transportation planning is not specifically addressed here because the intent is to show how air quality analysis should be carried out in relation to land use decisions. It is assumed that the future land use plans and decisions have been determined in relation to the overall goals and objectives of the region, and the focus is on analyzing the resulting air quality implications.

b. <u>Transportation Models</u>

Regional-level decisions regarding land use are generally analyzed using a region-level land use/transportation model, as described previously. The model follows the various steps, including trip generation, trip distribution, and network assignment, to determine traffic volumes and regional emissions. Within that basic modeling structure, various degrees of detail and various alternatives in actual methodology can be followed. For example, in a region with relatively high transit usage, modal split analysis should be of sufficient detail to show the impact of the land use decisions and transit travel. Growth in certain parts of the region may create a considerably higher transit usage than in others. In contrast, in a region with minimal public transit, the model split component is often left out of the model entirely.

Detailed submodels may also be needed for temporal variations in travel. As stated previously, certain land uses when concentrated on a large scale can distort the basic temporal travel patterns in that area. In such cases, specific peak-period analyses should be carried out. It may be necessary to specify these time periods even further and to develop hour-by-hour travel demands for the region if land use decisions are predicted to create significant changes in both the travel patterns and the temporal variations of these travel patterns. Such changes could be highly affected by oxidant formation in the region and could therefore be an important part of the air quality analysis.

Of practical interest in dealing with transportation models is the ability to transform their predictions to air quality model input. The primary area in which interfacing occurs is in the assignment stage of the transportation model. Various network analysis techniques are available that can convert traffic loadings on networks to grid-based input for air quality models. Preplanning of the complete set of analytical procedures can ensure compatibility among the different models and hence greater efficiency in the overall planning process.

c. Estimation and Forecasting of Emissions

Land use decisions have a direct effect on the spatial pattern of emissions, since changes in land use in any part of a region cause corresponding changes in industrial, residential, and travel patterns. The effect of such decisions on temporal variations in emissions is less clear. Urban travel generally follows fairly well-established temporal patterns owing to the mix of travel purposes (e.g., work, shopping, personal business), each of which has its own consistent temporal profiles. The combination of the various travel purposes creates an overall traffic pattern that seldom varies substantially throughout a region (or even from region to region).

Large concentrations of specific land uses can, however, distort the more generalized pattern of movement. For example, an industrial area catering largely to work trips creates high peak travel demands in its area of influence. Similarly, large concentrations of activities where there are special time-related patterns (e.g., sporting events, shopping) also distort the more generalized temporal patterns created by the normal mixture of activities. Since temporal variations in emissions can have important effects on photochemical oxidant at the regional level, the prediction of such temporal variations is an important part of the travel forecasting process.

Land use and transportation models, as described in the two previous sections are used to quantify the effects of land use plans on transportation patterns and future development. The output of these models is used in conjunction with estimates of emissions rates to develop a projected emissions inventory for use as input to an air quality model.

Evaluating a proposal at the estimated time of completion usually entails using transportation models in conjunction with current travel demand estimates. The trip generation, distribution, and network assignment phases are redone in accordance with the proposal. However, the future effects of the proposal may include expected shifts in the distribution of population and travel demand, which would require new projections of land use and transportation demand for air quality evaluation.

The emissions factors to be used should be applied specifically to the future year under consideration. Significant changes in average vehicular emissions occurring for many future years must be considered, along with changes in stationary source emissions factors that may affect the analysis. Some of these factors are discussed in the EPA's AP-42 document and its supplements [5]. Procedures for compiling emission inventories are discussed in Chapter III of Volume I of this report.

d. Air Quality Models

The material on air quality models presented in Chapter III contains most of the information required for land use analyses. The main considerations here are maintaining a balance between the level of accuracy in the emissions inventory estimates based on a given land use plan and the level of detail to be selected for the air quality model. The results of the air quality model should also be viewed for their qualitative value as indications of the relative merits of alternative plans. The analyses are of less value in producing estimates of actual concentrations for comparison with standards owing to the number of assumptions and uncertainties inherent in the analysis.

As discussed earlier, the pollutants to be considered are determined by legal requirements based on existing air quality. The level of spatial resolution to be used must be consistent with that of the land use plan, and the temporal resolution is determined in accordance with the applicable air quality standards. Also, selection of a model is subject to the constraints presented by the availability of data and the financial, physical, and personnel resources.

In some cases, it will be concluded that the requirements of the analysis are inconsistent with the available resources and data. If the collection of new data is prohibitive in cost and difficulty, it may be necessary to compromise by accepting a less desirable approach, perhaps eliminating spatial resolution or making extensive assumptions to permit the application of one of the more complex approaches so as to derive some guidance on the relative merits of planning alternatives. However, in such cases the results must be reviewed with more than the usual caution. The EPA is currently working on new guidelines for determining what analyses are to be considered legally acceptable.

D. TRANSPORTATION POLICY DECISIONS AT THE REGIONAL LEVEL

Before questions of routes and technologies can be considered, the transportation planning process must set up its regional goals, objectives, and policies to guide the development of plans and programs. Goals identify conditions that are theoretically attainable and provide principles for the development process. Objectives are more precise and quantifiable ends to achieve in advancing toward the goals. Policies define courses of action that will realize the goals and objectives.

Transportation policies thus have far-reaching effects on transportation. At the regional level, they often dictate how transportation funds are allocated, and they set overall priorities on how and where improvements are to be made. Facility planning and operations planning are almost always

performed within an overall policy framework. The degree to which the policies provide specific direction as opposed to general guidelines will depend on the particular responsibilities and authority of the regional government involved.

1. Types of Transportation Policy Decisions That Require Analysis at the Regional Level

Transportation policies must address the main transportation planning issues of the region. At one level, these are generalized expressions of intent, such as:

> The regional transportation system shall equitably serve the movement of both people and goods, it shall provide effective service to transit dependents . . ., and it shall be coordinated to provide a continuous functional system.

> Public transportation systems of the region shall be significantly improved . . ., and increases in public transit funding shall be sought, with particular emphasis on operating funds.

These types of generalized policies, which are simply a restatement of the regional transportation goals, provide a framework for examining issues and setting up specific policies.

Typical of the areas of concern in establishing specific regional policies are the following:

- Land use
- Accessibility and mobility
- Air quality
- Energy conservation
- Allocation of financial resources
- Organizational framework for implementation.

The first of these is covered under the land use category discussed previously. Examples of the type of regional policies related to the other five categories are given below.

a. <u>Accessibility and Mobility</u>

Transportation goals generally aim in broad terms to provide an efficient, multimodal system to transport people and goods, consistent with the best economic, social, and environmental interests of the communities in the region. Typical policies on accessibility and mobility include:

> Improvement of the highway and freeway system and integration of new or improved freeways into the transportation system to meet existing and future demand.
> Support for the development of circulation systems for high-activity centers.
> Provision for the efficient movement of freight.
> Improvement of ground access to and from both air terminals and harbor facilities.
> Provision of effective service for transit dependents.
> Provision of preferential treatment for bus-on-freeway, bus-on-arterial transit operation.
> Integration of subregional transit systems into the regional system, and development of minimum levels of local and feeder transit for all urbanized areas.
> Encouragement of the use of transit through provision of "park-and-ride" stations and improved transfer facilities.
> Improvement of services for the elderly, handicapped, and disadvantaged.

b. <u>Air Quality and Energy</u>

Conserving energy and improving air quality are part of the goals and policies of most regional agencies. Efforts to achieve these ends have

concentrated on reducing vehicle-miles traveled (VMT) through transportation control measures such as preferential lanes on freeways for buses and car pools (to encourage higher vehicle occupancy), ramp metering, improved signalization, and improved highway design. VMT-reduction policies are also intended to increase vehicle occupancy through traffic control measures, such as peripheral parking and exclusive lanes for high occupancy vehicles. Consideration may be given in some regions to weekend and special events travel, encouraging energy-conserving, nonpolluting transportation forms (e.g., through provision of bike paths and more public buses) for recreational travel.

The development of mass transit and feeder transit systems to reduce dependence on automobiles and the resulting demand for parking are typical of the policies in this category. Other policies focus on improving air quality by reducing the emissions of pollutants from mobile sources (autos, buses, trucks). Examples of regional policies for energy conservation and air quality control are:

> Improvement of facilities for high-occupancy vehicles on all freeways.

> Enforcement of the 55 mph speed limit.

> Development of pricing mechanisms, parking restrictions, and prohibitions on the use of autos in areas zoned for high-rise office buildings and in major activity centers, such as universities, sports centers, and shopping malls.

> Coordination of transportation programs to achieve state and federal air standards.

> Use of mass transit and feeder systems to reduce the demand for parking.

> Application of innovations in traffic control systems, such as exclusive lanes, to smooth traffic flow and favor transit vehicles.

> Implementation of transportation control measures to reduce the number of vehicle-miles traveled.

- Consideration of recreational areas in transportation plans, giving special consideration to energy-conserving and nonpolluting transportation forms (e.g., bikes, public buses).

c. <u>Allocation of Financial Resources</u>

Two important issues have emerged in recent years concerning the allocation of financial resources for transit: (1) optimizing the use of existing transportation funds, especially those for transit, and (2) seeking new funding sources and greater flexibility in the use of funds. Regional policies generally support a program of equitable funding that optimizes the use of capital funds and seeks new sources of transit funding, especially operating funds. A special concern here is the allocation of funds between regional and local transportation services.

Another problem is the establishment of policy directives dealing with major changes in the funding formula, such as diversion of highway funds to transit or the funding crisis now facing highway construction and maintenance (resulting from limited growth in gas tax revenues while operations and maintenance costs have increased sharply). Examples of regional policies on the allocation of financial resources are:

- Ensurance of continuing funds to maintain adequately and to improve the street and highway system.
- Development of an equitable program of transit funding to support transit districts and municipal transit operators.
- Search for increased transit funding, with an emphasis on operating funds.
- Provision of a soundly managed, fiscally responsible transit system.

d. Organizational Framework

The earlier discussion on the definition of a region has pointed out that regions are usually multijurisdictional, and implementation responsibility is generally vested in organizations other than the regional agency. Policies must therefore be defined that establish decision-making procedures, define institutional frameworks, and set up coordination procedures for implementation. Although these policies are of secondary importance in the context of the guidelines given in this manual, examples of such policies are listed below:

> Implementation of methods for community involvement in plan development and decision-making.

> Coordination of safety programs among all participants of the regional transportation planning process.

> Support for legislation facilitating city-county implementation of transportation programs.

> Support for joint efforts for regional transit system development and promotion of coordination of all bus systems, including municipal and school bus systems, to encourage greater efficiency in the use of equipment.

> Development of an organizational structure responsible for continuous development and implementation of the transportation plan.

> Development of an implementation program whose priorities and schedules are based on realistic financial, geographical, and political constraints.

2. Required Air Quality Analyses

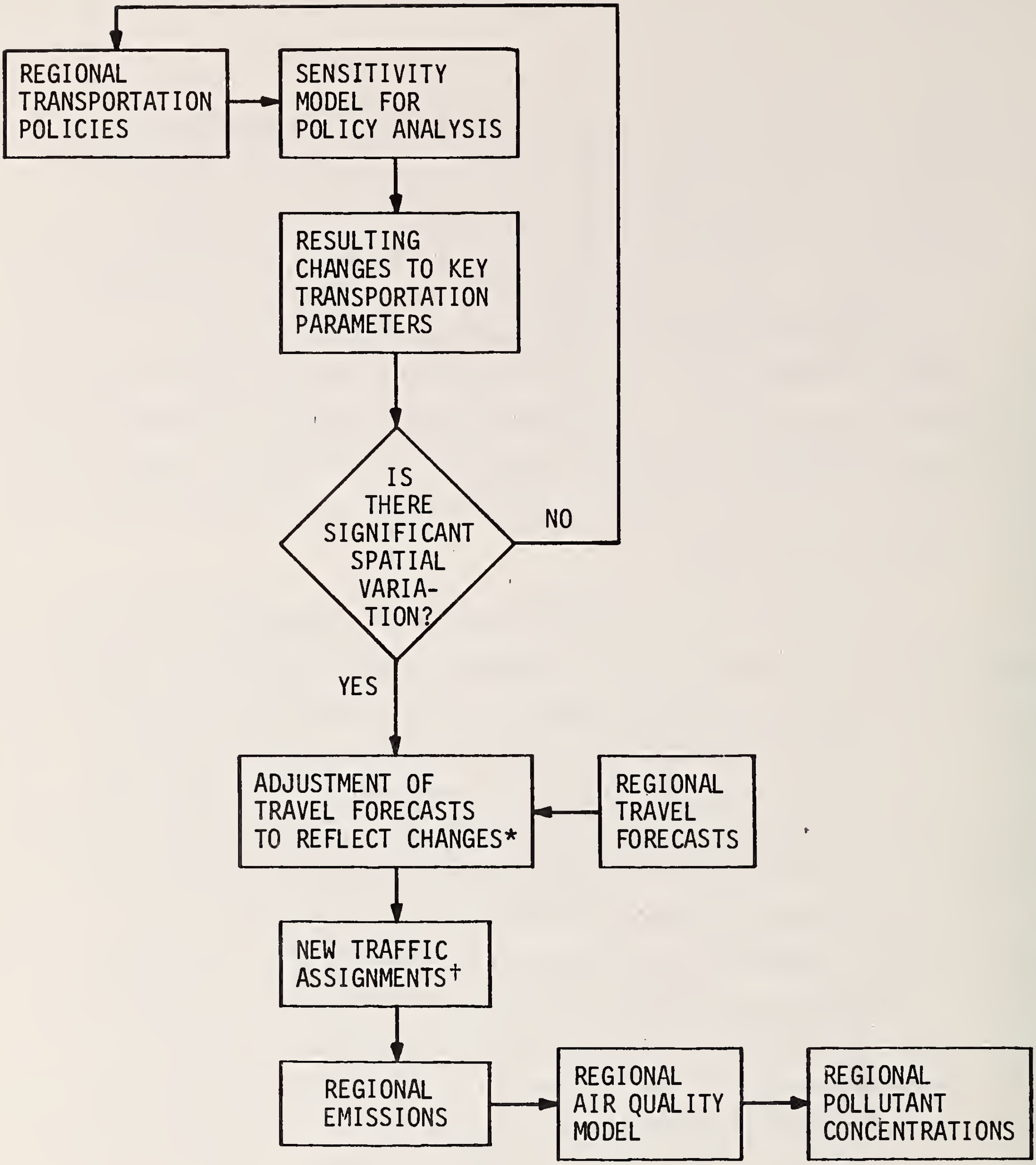
a. Transportation Models

The analytical tools required for analyzing transportation policies at the regional level are similar to those used for analyzing land

use decisions: regional-scale transportation and air quality models. However, another class of transportation models, commonly called sketch plan or policy sensitivity models, are widely applicable to transportation policy decisions. Their main feature is the ability to determine the implications of various policies for a region by dealing with sensitivity rather than absolute values. They may vary from simplified regional transportation models (i.e., having aggregated larger zone sizes) to simple policy-sensitive relationships that equate various transportation parameters with policy variables. Typical examples of the latter are the sensitivity of VMT to pricing and the changes in travel mode due to transit improvement strategies.

Although the policy models are efficient and useful for analyzing the transportation implications of policy decisions, their application is more limited for air quality analysis. In many cases, the models do not simulate area-wide networks and therefore do not directly produce spatially oriented vehicle mileage data. Thus, these simplified policy models need to be converted to data forms that can be utilized by the air quality models. Generally, this task requires the application of a regional transportation model that can directly interface with the regional air quality models. Figure 5 presents a simplified flow diagram form of how this interfacing would occur. The intent of the policy model is to provide a mechanism for examining many different policies without using the large-scale model for each case. Interfacing with the air quality model requires choosing several significant sensitivity points and applying these to the large-scale model.

In this mechanism, analysis of transportation policy decisions is essentially a two-step process rather than a direct analysis process. The first step requires translating transportation policies to sensitivity results, which can then be applied to a regional transportion model. Output from the regional transportation model is then used in the regional air quality model to examine the corresponding air quality implications.



* Either through manipulation of previous model output or through new model runs.

† Assignment portion of the model.

FIGURE 5. ANALYSIS OF POLICY DECISIONS BY A SIMPLIFIED POLICY MODEL

Applying this mechanism to determine the best of a series of alternative proposals may not require carrying out the entire process for each alternative. In cases where it can be demonstrated partway through the process depicted in Figure 5 that certain options are clearly less attractive than others, further analysis may not be needed. This screening of alternatives can occur at any stage of the process with the potential for substantial savings of time and expense.

b. Estimation and Forecasting of Emissions

Transportation policy decisions seldom have a direct effect on spatial and temporal variations and emissions. However, they do have an indirect influence. Policies set the framework for actual implementation plans, which then determine the amount and pattern of travel and hence the spatial and temporal patterns of emissions. For example, if specific transportation policies affect travel in certain portions of the region differently, the overall emissions pattern will be altered. Similarly, if transportation policies affect the modal distribution (e.g., by creating more transit use in a particular area), the spatial emissions patterns will be changed. Temporal emissions patterns can be influenced by policies that affect the temporal pattern of travel, for example, implementation of staggered work hours or high-occupancy vehicle usage during peak periods.

Projected emissions inventories that are developed from policy plans may include numerous assumptions to bridge the gap between policy statements and emissions rates. Therefore, inventories developed from policy plans are more valuable in comparing the relative merits of alternative policies than in evaluating compliance with air quality standards. The assumptions made may include sufficient flexibility that a wide variety of reasonable possibilities for future levels will usually exist. A "most likely" case should be identified for which emissions rates are estimated,

but such estimates should be used with caution. Sketch plan models can be used to generate emissions inventories for a broad view of the air quality implications of policy plans. Since these implications are even coarser than ordinary policy plans, the caveats presented above should be considered even more strongly.

Transportation models are used to generate a new traffic assignment for each alternative policy under consideration at ETC and ETC + 20 years. These predictions of traffic may be made at a wide range of spatial and temporal resolutions, depending on the policy itself and the availability of the appropriate transportation models. In any case, emissions inventories are generated using the procedures described in AP-42 and its supplements [5] and in Chapter III of Volume I.

c. Air Quality Models

The information concerning model selection presented in Section IV.B also applies to policy planning. However, it should be understood that the results are more useful for qualitative rather than quantitative evaluation. As in land use planning, the projected emissions inventories for policy plans are likely to be the weak link in the chain of procedures leading to air quality estimates.

Sketch plan models are compatible with the modeling techniques discussed earlier. The air quality modeling techniques not based on grids are compatible with sketch plans that include no spatial stratification. For grid-based sketch plans that feature a high level of aggregation, the grid-based models of comparable resolution can be used. Of course, the detail of these models is so coarse that they should be used to indicate the implications of a policy rather than to determine compliance with air quality standards in a formal air quality analysis. By their nature, sketch plan analyses are appropriate for use in screening alternative proposals to determine which should receive more complete analysis.

E. FACILITY AND OPERATIONAL PLANNING DECISIONS

Facility and operational planning decisions most directly affect the flow of traffic. Whereas land use creates the demand for travel, transportation facilities determine the extent to which that demand can be fulfilled. The concern in this section is with the actual physical facilities, such as highway and transit systems. New facilities create travel through areas that previously had little or no traffic, and improvements to existing facilities both improve the quality of traffic flow and divert some traffic from other parallel facilities. Operational changes largely affect the quality of traffic flow but also influence the level of usage of different modes and the pattern of travel movement.

1. Types of Facility and Operational Planning Decisions That Require Analysis at the Regional Level

The decisions in this category concern three types of implementation options: new facilities, facility improvements, and operational changes. Implementation plans may involve one or a combination of any of these three types of implementation options. For new facilities and facility improvements, the decisions are generally concerned with location and design. Operational changes, which can take a variety of forms, affect the level of service on the highway system, the usage of different modes, and the preferential treatment of different vehicle types.

As stated earlier, implementation of transportation programs is seldom the responsibility of regional agencies. Although land use plans and transportation policies set the overall regional framework, they leave implementation to other jurisdictions within the region. For these types of planning decisions, therefore, the subregional category is the appropriate level of focus. However, some regional plan components do imply a need to examine the implications of facility and operational planning decisions at the regional level. Some typical examples are described below.

a. Highway Improvement Plans

Long range highway improvement plans, particularly those of the high-level regional infrastructure such as the freeway system, are often the responsibility of the regional agency. The freeway system is generally under the jurisdiction of a state highway department and is therefore the concern of the region and the state. Since implementation is not a function of smaller jurisdictions within the region, the regional agency in cooperation with the state is responsible for highway improvement plans.

The planning process generally takes the form of identifying existing deficiencies, forecasting future traffic demand, identifying future deficiencies, and designing improvement plans. The primary analytical tool is the region-wide transportation model described earlier, and the emphasis is on regional system-wide planning rather than detailed planning for specific facilities within that system.

b. Transit Plans

Traditionally, public transit has been provided by individual jurisdictions. With the advent of state and federal support for transit, a more integrated approach to systems planning is being followed, and coordinated public transit plans are increasingly becoming the responsibility of a region. This gives the opportunity for maximizing the potential level for transit in those areas having the greatest transit propensity. The implications for air quality analysis are in the corresponding changes in VMT that arise through implementation of a regional transit program.

The quantitative analysis generally follows from the modal split portions of the regional transportation model. The model produces different vehicular travel patterns for different transit plans. These patterns in turn are translated into different emissions inventories for

the region. The modal split portion of the transportation forecasting model must be sensitive to the various system parameters being considered in defining the regional transit plans. Such sensitivity will then directly translate to the changes in vehicle emissions required for the air quality analysis.

c. Traffic Operations Improvements

Continuing programs are being carried out utilizing traffic operations improvements to increase safety and capacity. Many special programs have been federally mandated or supported, as exemplified by the present transportation system management programs now being pursued by local and regional agencies. At the regional level, certain operations programs are more appropriately considered under the transportation policy decisions category because they are in the form of broad policies that affect traffic operations. Other more specific policies on implementation strategies can be analyzed as actual improvement programs. Examples of regional traffic operations improvement programs that can be considered as operational plans at the regional level are:

> Area-wide signal system standardization and improvement
> Regional parking management
> Region-wide safety plans
> Vehicle maintenance programs.

Wherever the regional program is specific enough to be translated to changes in volumes, speeds, or levels of service, it can be considered under facility and operational planning decisions.

d. Freeway Operations

In the past, freeway operating characteristics have largely been a function of freeway design and traffic demand. Level of service has

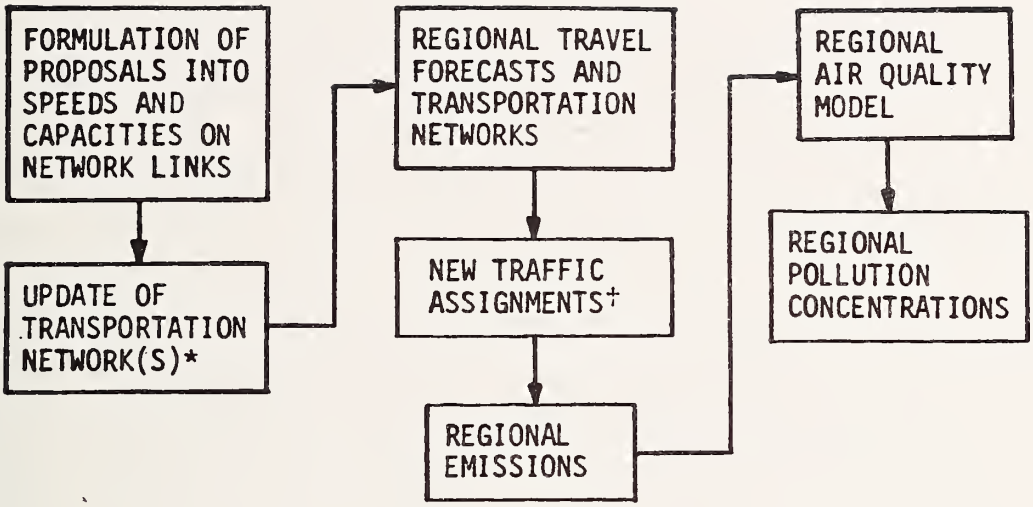
been a design criteria, but actual performance has been a product of these two factors. In recent years, interest has grown in developing operational techniques that can allow freeways to operate at desired levels of service.

The most common form of controlling freeway operations is ramp metering, which basically enables freeway volumes to be kept at pre-specified levels. By regulating volume/capacity ratios, the freeway can be maintained at levels that produce the desired level of service. Such programs are generally developed at a regional level because freeway travel involves the complete regional freeway infrastructure. Also, the overall effect of such a program is a regional concern.

Typical effects of ramp metering include higher traffic volumes on other portions of the street network, such as arterials, and decreased use of the freeway system for short trips. The overall effect of such a program is particularly significant for the average-speed and level-of-service components of the traffic flow variables. Changes in VMT may be slight, but the changes in level of service and average speeds can substantially affect emissions.

e. High-Occupancy Vehicle Programs

One transportation system management strategy is the use of high-occupancy vehicles. In its simplest form, this strategy is implemented through car pooling and van pooling. As far as operational decisions are concerned, it may take the form of priority treatment for such vehicles, for example, exclusive freeway lanes for high-occupancy vehicles, special treatment at entrances to freeways, and priority transit treatments on the surface street system.



* Highway and/or transit.

† For significant changes, this may involve running the distribution and modal split portions of the model as well as the traffic assignment.

FIGURE 6. ANALYSIS OF FACILITY AND OPERATIONS PLANS

2. Required Air Quality Analyses

a. Transportation Models

The main effects of facility and operational plans are inherently of corridor scope, though certain plans may be analyzed at a regional level (e.g., a regional transportation system management program). As in the previous categories, a regional transportation model is used. For examining the implications of alternative facility and operational decisions, the land use and trip generation portions of the model can be held constant, assuming that the various facility and operational plans being considered do not change the land use pattern. The quantitative analysis can thus concentrate on the trip distribution modal split and network assignment portions of the model.

Figure 6 shows in simplified form the type of application required for examining facility and operational plans. In general, the regional analysis forms the basic framework for subregional analysis. Certain aspects of the alternative plans can be assessed at the regional level, but much of the detailed analysis must be carried out on a smaller scale to address fully the implication of facility and operational plans.

b. Estimation and Forecasting of Emissions

Facility and operational planning decisions have a direct effect on the spatial and temporal emissions patterns. The location of new facilities and of facility improvements directly influences emissions in that particular area. Operational changes, though implemented on a regional basis, often affect one portion of the region more than another.

Temporal patterns are less directly affected, though local changes can have significant indirect effects. For example, freeway operations

strategies such as those discussed above may greatly improve the level of service during peak periods. Although such measures may not change the temporal pattern of VMT, they do change the associated pattern of emissions. The result may be a more even temporal pattern of emissions relative to the heavy peaks associated with high volumes and low levels of service during peak periods.

In facility and operational planning, traffic levels are directly affected. Consequently, it is possible to develop reasonably accurate quantitative estimates of vehicular emissions that would occur as a result of adoption of the plan. Emissions estimates are based on emissions factors projected to the appropriate years, ETC and usually ETC + 20. The use of accurate and realistic emissions inventories as input to air quality models renders the model predictions themselves more reliable for comparison with air quality standards, in contrast to land use and policy planning, where the reliance on assumptions to bridge the gap between the statements of the plans and the actual emissions figures can be greater.

c. Air Quality Models

The air quality modeling issues for facility and operational planning are quite similar to those outlined earlier for land use and policy planning. The main difference is that emissions inventories for this type of analysis are the most accurate of those for the three categories, as described in the preceding section. Therefore, the predictions of the air quality analysis are more likely to be accurate in an absolute sense. Owing to their additional accuracy, the more complex modeling techniques are attractive for comparisons of air quality with standards. In this category, the models are best suited to answer the question of whether regional air quality will be within air quality standards if the facility or operational plan under consideration is adopted.

F. SUMMARY

The methodology used to evaluate the air quality impact of a transportation planning proposal should be capable of assessing compliance with federal and state air quality standards, PSD requirements, and perhaps State Implementation Plans. To satisfy legal requirements, these techniques must either be recommended by the EPA or independently demonstrated to be adequate. Ongoing EPA-sponsored research is being performed to provide a better working definition of "adequacy" through the development of performance standards and evaluation criteria.

Within the range of EPA-approved models are a variety of methods, whose accuracy depends on the nature of the transportation plan, the availability of input data, the general meteorological and topographical character of the area, and other factors. Determining which models are most appropriate requires judgment based on an understanding of these issues and an assessment of the ability of the chosen model to treat the relevant phsyical and chemical processes. This report includes rough estimates of the general level of accuracy of the various techniques; however, these estimates vary for specific situations.

In some situations, the financial resources or personnel required for the most complete level of analysis may not be available; thus, a monitoring program may be necessary. The decision as to which modeling technique should be used in these situations must be balanced against the desirability of additional accuracy in view of the additional cost incurred.

V SUBREGIONAL-LEVEL PLANNING

This chapter discusses subregional transportation planning in relation to air quality, first defining what is meant by the term "subregion," then describing the types of transportation problems and decisions encountered, and finally, presenting the related air quality considerations. Subsequent sections discuss each of the categories of problem and decision types individually, providing guidance for incorporating air quality analyses into the relevant transportation analysis process.

A. DEFINITION AND DESCRIPTION OF SUBREGIONAL-LEVEL PLANNING

1. Definition of a Subregion

The term "subregion" is used in this manual to denote an area for which transportation planning analyses are undertaken that lies within a larger region. Subregions range in size from large, jurisdictionally autonomous areas, such as cities, to small specific localities, such as shopping centers, but they do not include entire urban areas. Since a subregion is only part of a larger region, its transportation facilities and air quality are significantly influenced by the surrounding region.

a. Types of Subregions

Subregions differ both in absolute size and size relative to the regions containing them. For the purposes of these guidelines, subregions are considered under three basic groups:

> <u>Subarea</u>--a distinct area for planning purposes. It may be a city, group of cities, county, or any other appropriately defined area that must be considered as a single

entity for the particular transportation or planning questions being addressed.

> Corridor--a linear portion of a subarea or region for which questions pertaining to that corridor alone are being analyzed.

> Specific locality--a small, localized area for which a particular transportation problem specific to that location is being analyzed. Specific localities range in size from a single intersection to a distinct portion of a region, such as a central business district.

The types of subregions and transportation problems encountered vary considerably, as do the analysis techniques used to address them. Despite this variation, the analytical techniques applied to study air quality in each type of subregion exhibit a basic similarity.

b. The Difference Between a Subregion and a Region

Although a subregion may be either small or a major portion of a region, the transportation patterns and air quality of the subregion are influenced by other portions of the region. In contrast, a region is more self-contained; few factors external to it affect its transportation patterns and air quality. The term "subregion" is defined in such a way that many types of transportation analyses are performed at this level. These subregional analyses share the common characteristic of generally considering external, or regional, factors that are defined by the region and that form the basic transportation and air quality setting for the subregion.

2. Jurisdictional Relationships

Like the definition of region, the definition of subregion does not imply any jurisdictional relationships; both can be multijurisdictional. In a transportation planning context, however, subregions are more likely to have single jurisdictions, because many planning functions are carried out

at a city or other planning area level. The fact that a planning function is carried out for a specific subregion often indicates the existence of a single jurisdiction responsible for that planning.

The smaller subregions, such as specific localities, usually have a single jurisdiction--either the particular city or county in which the locality is contained, or a particular community within that city or county. In either case, the primary planning function concerns only one jurisdiction.

For large subregions containing several jurisdictions, coordinating relationships are required as in the regional situation. In this case, planners must interface with higher levels of government, such as the county, by working with a regional agency, local highway department, or other larger scale jurisdiction involved in the planning process. Where effective regional planning is being carried out, the appropriate organizational mechanisms may be a part of the regional planning function.

3. Types of Transportation Planning Problems and Decisions

As discussed in Chapter IV, three basic types of problems and decisions require transportation analysis:

> Land use
> Transportation policies
> Facility and operational plans.

Separation into these groups does not imply independence, since many transportation problems and decisions involve more than one of the three groups.

At the subregional level, the implications of the three problem types can differ somewhat from those at the regional level because subregions are more likely to have agencies with the authority to implement transportation proposals. The decisions therefore have a direct effect on transportation

and resultant air quality. These three problem types are examined below for the three basic groupings of subregions: subareas, corridors, and specific localities. Both the problem types and the analysis techniques tend to differ for each.

a. <u>Land Use</u>

At the subregional level, decisions regarding land use revolve around local growth and interpretation of zoning plans. Most subregions either have or are part of an area that has a general plan setting the basic zoning of the area and hence establishing the land use pattern. Growth generally takes place within this land use plan and is subject to its zoning constraints. Although a general plan sets the zoning, the rate of development in different areas is affected by various factors. Zoning generally does not imply forecasts of activity or growth: It merely shows where and what kind of growth is to occur.

The geographic distribution of growth has important implications for transportation and air quality. The distinction must therefore be recognized between land use decisions related to zoning and those that can influence growth. Examples of the latter are growth management plans, which attempt to channel growth into predetermined areas at predetermined rates.

Examples of land use proposals are as follows:

> Zoning and land use planning
  - General plan formulation
  - Growth management plan
  - Land use plan implementation strategies
  - Zoning changes
  - Revitalization programs
  - Open space and recreation plans

> Residential development
  - Residential density plans
  - Housing mix (multiple versus single family)
  - Subdivision approvals
  - Redevelopment plans
> Nonresidential development
  - Downtown redevelopment
  - Regional shopping center
  - Community shopping center
  - Commercial development
  - Industrial development
  - Special land uses.

Each of these types of proposal will have an impact on travel patterns and hence on air quality.

b. Transportation Policies

If a subregion is sufficiently large (i.e., a subarea), it may have specific policies for transportation that need to be analyzed at the subregional level. Ideally, they should be consistent with the regional policies, either adding to the regional policies or providing more specific guidance for local implementation programs. Generally, the policies being analyzed at the subarea level involve specific actions that affect travel patterns, such as parking restrictions or prohibition of traffic in a central business district.

Transportation policy questions for a subarea are analyzed by adjusting travel demand and modal splits in accordance with the proposed policy and then evaluating the resultant effects on subarea emissions and air quality in the same fashion as for other types of subarea analysis. With the exception of subarea analysis, policy decisions are of minor importance in subregional planning and are consequently not discussed further in this report.

c. <u>Facility and Operational Plans</u>

This decision category is the most important at the subregional level. Facility and operational plans determine where and how traffic will move, what will be the corresponding level of service, what proportions will be carried by which mode, and so forth. The plans generally evolve around the need to serve the present and future land use patterns. Transportation policies may provide overall guidance as to how the land use can be served. However, within that framework, many options are available, and many decisions must be made regarding actual plans.

The following are examples of the types of proposals that arise in this category:

> New facilities
  - New highway corridor
  - Existing highway realignment
  - Freeway access (interchange)
  - Arterial link
  - Additions to local street system
  - Rapid transit corridor
  - New bus routes

> Improved facilities
  - Freeway lane increases
  - Interchange improvements
  - Arterial street reconstruction
  - Local street upgrading
  - Transit service upgrading

> Operations
  - Freeway access control
  - Coordinated street signalization
  - Area-wide signal system

- Traffic management strategies
- Speed restrictions
- Parking
- Transit priority treatment.

Many plans contain several of the activities listed above, particularly if the area under consideration is a corridor or subarea.

B. AIR QUALITY ANALYSIS AT THE SUBREGIONAL LEVEL

1. Goals of the Analysis

The air quality analysis problems encountered at the subregional level involve primary air pollutants, such as carbon monoxide, and often secondary pollutants, of which photochemical oxidants (principally ozone) are most important. Whether the analysis should focus on primary or secondary pollutants or both is determined largely by the size and scope of the proposed project and whether the project involves a corridor, a specific locality, or a subarea. Because secondary pollutants are not emitted directly to the atmosphere, but rather are formed from primary pollutants after some period of time, in certain instances it may be appropriate to consider only the impacts of primary pollutants in the immediate vicinity of the emissions source. In other cases, however, particularly if the anticipated transportation emissions represent a sizeable fraction of the total emissions in the subregion, both primary and secondary pollutant impacts may have to be analyzed. This section discusses both types of analysis.

The National Ambient Air Quality Standards of principal interest at the subregional level relate to carbon monoxide and oxidant (ozone). For carbon monoxide, one-hour-average and eight-hour-average concentrations are not to exceed 40 mg/m^3 (35 ppm) and 10 mg/m^3 (9 ppm), respectively,

more than once per year. The one-hour-average concentration of photochemical oxidants (corrected for nitrogen dioxide) is not to exceed 160 $\mu g/m^3$ (0.08 ppm) more than once per year.* In addition to these two pollutants, others may have to be considered as well.† For example, some transportation system configurations might lead to high concentrations of nitrogen dioxide, reactive hydrocarbons, or suspended particulate matter, to which various state and federal air quality standards pertain.

Generally, the air quality standards of greatest concern at the subregional level are those pertaining to short term averages (i.e., one hour, three hour, eight hour); however, in some cases it may be necessary to consider longer term averages as well. For example, both primary and secondary standards have been set for annual averages of NO_2, SO_2, and suspended particulates.

Air quality issues at the subregional level vary from specific to broad. Accompanying this range in the complexity of issues is a similar variation in the difficulty of their resolution. On the one hand, air quality concerns arising over a proposed new corridor are generally well defined; the issues to be resolved and the techniques for addressing them are normally easily identifiable. On the other hand, subarea plans often raise complex air quality issues requiring sophisticated analysis procedures. The ranges of issues, problems, and techniques for their solution are discussed below (see Chapter III for a review of available resources).

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* Note that some states have air quality standards slightly different from the federal standards. Thus, highway planners must be cognizant of the most restrictive standards.

† A short term standard for nitrogen dioxide is currently under consideration by the EPA, and it appears very likely that one will be promulgated in the near future.

2. The Subregional Transportation Model--A Subset of the Regional Model

This modeling situation follows the basic model structure of the corresponding regional model. For the subregion being examined, a refined zone system is developed by subdividing the zones used in the regional model. A more detailed subregion network is then developed corresponding to the refined zone system. The actual relationships used in the model can then follow directly from those in the regional model. For example, trip generation equations, trip distribution functions, and modal split relationships can be identical to those in the regional model. Alternatively, certain portions of the modeling relationships can be refined to achieve greater accuracy or to better reflect local characteristics. For example, in the trip generation stage, a finer level of socioeconomic characteristics may be used to reflect local travel patterns.

The actual application of the subregional model can be carried out in two ways:

- The complete regional model can be run with the refined zone system and network for the subregion incorporated into the input data. This procedure duplicates the regional model data but gives a finer level of detail in the subregion being studied.
- Data from the regional model for the portion of the region outside the subregion can be compressed into a simplified form to provide external trips. These are then added to the local trips as determined from the subregional model. This procedure has the advantage of relying on a smaller modeling process, though some accuracy will be lost if the area has a high external trip component.

The procedure followed will depend on such factors as the availability of a regional model, the external characteristics of the subregion, the ability of the regional model to be restructured to include the subregion, the

accuracy necessary in the results, and the available resources for performing the modeling.

Regardless of the method chosen, the final modeling output is a set of assigned volumes on the subregional network. For situations with low transit service, this consists of traffic volumes on the highway network. If transit is a substantial portion of the transportation system, then the model will incorporate a modal split function, and the final results will also provide estimates of passengers on the transit system. As in regional modeling, special features can be incorporated into the subregional modeling process, such as the ability to estimate peak-hour relationships and to balance traffic flows with available capacity (capacity restraint assignment).

3. Separate Subregional Models

In the absence of a regional model, a subregional transportation model with the same capability as that discussed above is generally developed. For the external component, various strategies are used. Ideally, some form of survey data can provide information on present external origins and destinations. When this is not the case, approximation methods must be used. In one such process, cordon counts are established for the area being studied, and the internal travel patterns that create these external volumes are estimated. When forecasting this external component, one must estimate future cordon volume totals on the basis of future trends and other local characteristics.

For the internal portion of the model, the degree of sophistication depends on the data available for model calibration. If comprehensive origin-destination information exists, a complete and detailed calibration can be made. In the absence of such data, modeling relationships from other areas with similar characteristics are generally used. The model is run for a base year with successive adjustments to the modeling relationships

until reasonable comparisons are obtained between base year traffic counts and base year modeling forecasts.

4. Corridor Analysis Techniques

If the scale of analysis is a corridor, more simplified techniques can be used. Ideally, the resources of a complete subregional model would be available, and changes in the corridor that require analysis could then be directly modeled using this capability. In the absence of such a model, however, other techniques can be used to obtain the necessary travel forecasts.

The term "corridor analysis" is used to refer to the type of modeling that concentrates on a specific corridor or corridors. Traffic volumes in the corridor are related to the land use in the area of influence of the corridor. Changes in the activity level of this land use produce a commensurate change in corridor volumes. By relating the change in corridor volumes to changes in the surrounding land use, traffic volume estimates can be made. The technique is less useful when the problem being analyzed requires major changes in the network. The corridor model therefore has the advantage of simplicity and ease of application, but it is limited in its ability to predict traffic for certain situations.

5. Specific Locality Models

For a specific locality, a typical problem is the traffic impacts of a proposed development such as a subdivision, industrial facility, or commercial center. The area of influence in a transportation sense is relatively small, and only the traffic impacts on a small portion of the surrounding highway network need be examined. Sometimes only the trip generation portion of the typical modeling sequence is utilized. Trips are generated for the facility in question and applied to the surrounding

street network. For larger situations where the impact is greater, a limited trip distribution may be carried out to determine the relative proportions of trips to and from the facility from different directions. A simplified assignment is then carried out to reflect this distribution.

Although these types of techniques are relatively simple in structure, they can also involve a greater amount of detail. For example, the temporal distribution of trips is likely to be of primary importance (because of the need to analyze peak periods). Similarly, trip characteristics such as parking duration are often required. The traffic volume forecasts on the street network may be more detailed. At critical intersections, the number of turning movements is required so that detailed capacity analysis can be carried out. Other refinements may include the proportion of commercial vehicles and the relative mix of commercial and private vehicles during different periods of the day. This greater level of detail contrasts with the more generalized daily volumes produced by a regional transportation model or a subregional model. Most large-scale transportation models are unable to provide a high degree of detail or accuracy at the specific locality level.

6. Other Techniques

The four types of modeling techniques described above cover the general range of traffic volume forecasting procedures used in transportation planning. In many cases, less rigorous procedures will be applied to estimate the required traffic volumes. Extrapolations based on past trends are a common means of estimating future volumes on certain facilities. Adjusting the trends according to predicted area-wide growth rates is a first-order refinement of this process.

A common procedure employed in many analyses is to make simple adjustments to modeling data. This obviates the need to perform complete model runs and therefore results in cost savings at the expense of some loss in

accuracy. The situation being tested is compared with that of the original model run, and adjustments to the forecast data are made accordingly. Since there is seldom a well-defined adjustment process, this procedure requires a knowledge of the modeling process and a certain amount of subjective judgment.

C. LAND USE PLANNING DECISIONS

1. Types of Land Use Planning Decisions That Require Analysis at the Subregional Level

Land use decisions at the subregional level generally represent the results of specific implementation proposals. These can vary from area-wide zoning plans to development proposals at a specific locality. Because of the effect of land use on traffic, each proposal has air quality implications that need to be assessed as part of the transportation analysis.

The types of land use proposals and decisions requiring transportation analysis fall into three groups:

- Zoning and land use planning
- Residential development
- Nonresidential development.

Table 3 gives examples of land use proposals in each group. Since the size of the subregion affects to some extent the types of land use proposals to be considered, this table indicates the applicability of each example for the three different subregional area designations.

These examples show the types of applications requiring analysis, but the analysis procedures depend on such factors as size of area, planning time frame, and data availability. For example, the analysis of a residential development is similar to that of a nonresidential development in a

TABLE 3. EXAMPLES OF LAND USE PROPOSALS AND TYPES OF SUBREGIONS CONSIDERED IN ANALYZING THEM

Land Use Proposal	Type of Subregion		
	Subarea	Corridor	Specific Locality
Zoning and land use planning			
General plan formulation	XX		
Growth management plan	XX		
Land use plan implementation strategies	XX		
Zoning changes	X	X	XX
Revitalization programs	X	XX	XX
Open space and recreation plans	XX	X	XX
Residential development			
Residential density plans	XX		
Housing mix (multiple vs. single)	XX		
Subdivision approvals		X	XX
Redevelopment plans	X	X	XX
Nonresidential development			
Downtown redevelopment		X	XX
Regional shopping center	X	XX	X
Community shopping center		X	XX
Commercial development	X	X	XX
Industrial development	X	X	XX
Special land uses	X	X	XX

XX = highly applicable.
X = some applicability.

specific locality. If an overall area-wide development pattern is being studied, however, the analysis procedures differ somewhat because of the larger scale of the analysis.

The key concerns in undertaking a transportation analysis are as follows:

> Size of area. The three categories (subarea, corridor, and specific locality) provide appropriate descriptors of the size of area involved.

> Planning time frame. Short range decisions may involve immediate proposals, whereas longer range plans may have projections 10, 20, or 30 years hence. The analytical requirements will differ under different time frame situations.

> Quantification. Certain land use proposals and decisions are readily quantified. Others may be more broadly stated and may be more like policies rather than actual proposals. For example, land use zoning shows where different land uses should be located. While definitive in nature, land use proposals are difficult to quantify for the purposes of transportation analysis because zoning does not imply a particular rate of growth. Since it is necessary to quantify land use proposals for air quality analyses, the transportation analysis procedure can differ according to the quantification of the initial problem.

In terms of air quality analysis, therefore, the type of land use situation being studied is less important than the characteristics presented above.

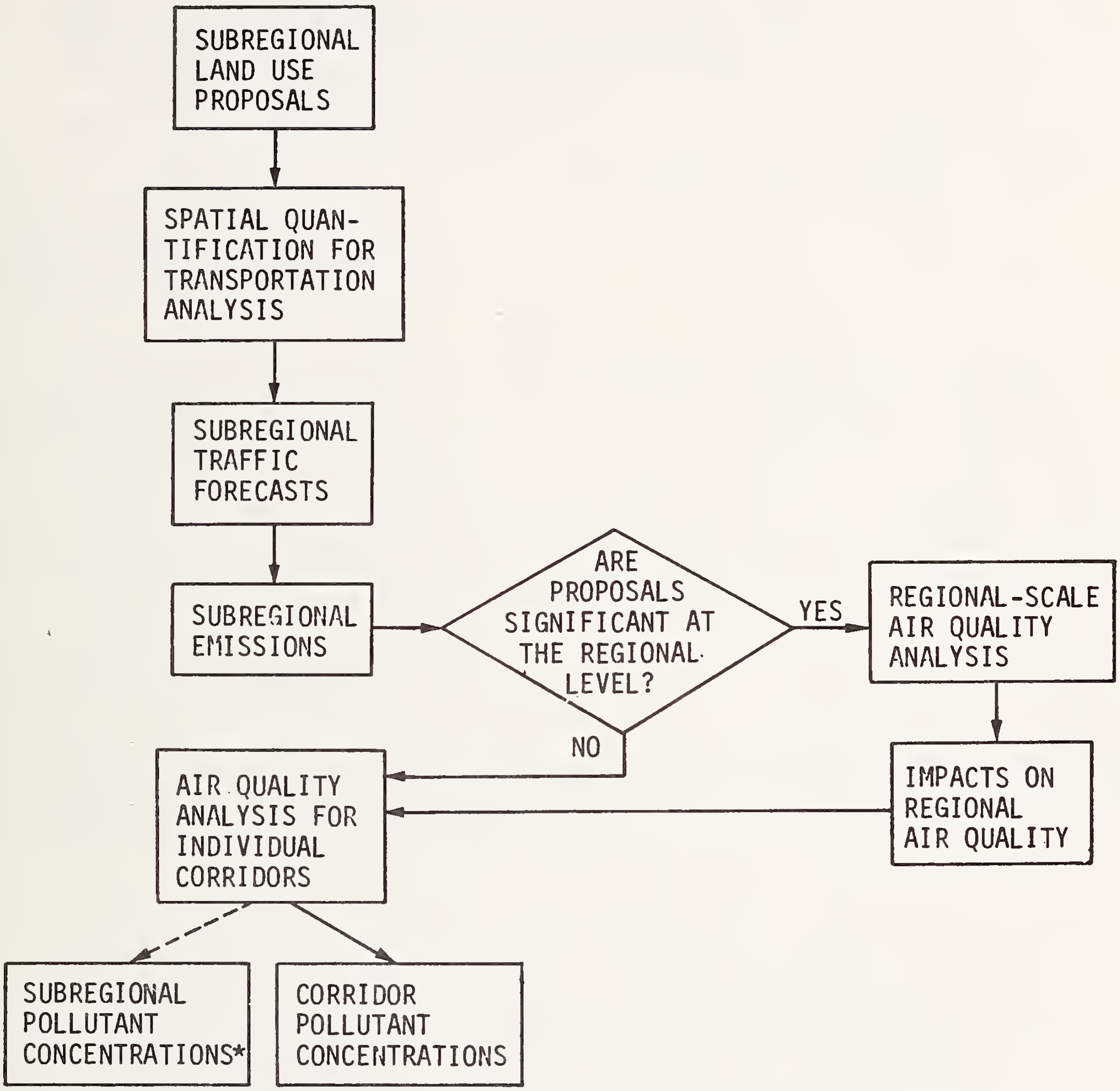
2. Required Air Quality Analysis

A variety of decisions and problems must be analyzed at the subregional land use planning level. The various types of transportation models that

can be used for quantitative analysis of these decisions and problems were discussed in Section V.B and in Chapter III. The actual tools applied depend partly on the type of problem being analyzed but more specifically on the subregion's size, planning time frame, and quantifiability. The size of area dictates whether a complete subregional model should be used or whether a specific locality simplified model can be used. (Thus, subsequent sections of this chapter treat air quality analysis in more detail at the corridor, specific locality, and subarea level.) Similarly, the planning time frame determines the extent to which longer range land use forecasts are needed as input to the transportation model. Quantification involves two problems: quantification of the actual land use decision being studied and the degree to which data are available to carry out the required quantification.

Air quality analysis in the planning process requires three primary modeling tools. The first two are the air basin grid or trajectory models used for analyzing the regional-scale effects of subregional proposals. The third is the corridor diffusion model, which is utilized regardless of the size of the subregion. Since the corridor diffusion model is corridor-specific, modeling a larger area requires grouping corridors together. Figure 7 depicts the general process of analyzing land use proposals at the subregional level. As shown in this diagram, part of the analysis is an appraisal of whether the particular proposal is significant at the regional level. If it is significant, then a regional-scale analysis must be performed to determine how the proposal will affect other portions of the region.

Within the subregion being considered, critical corridors are examined using a microscale air quality model. Where appropriate (e.g., larger subregions) an aggregation of emissions is made to analyze the overall effect of the proposal. The final results thus indicate the air quality impact at the regional, subregional, and corridor levels.



* Represents accumulation over several corridors for subregions where this is necessary.

FIGURE 7. ANALYSIS OF LAND USE PROPOSALS AT THE SUBREGIONAL LEVEL

3. Estimation and Forecasting of Emissions

As discussed in Chapter IV, land use decisions directly affect the spatial pattern of pollutant emissions. Changes in land use in any part of a subregion will cause changes in travel and hence in vehicular emissions. The extent to which this is important depends on the size of subregion being considered and other factors.

The effects of land use decisions on temporal variations in emissions are less direct but nevertheless important. As stated in Chapter IV, urban travel generally follows fairly well-established temporal patterns. The various travel purposes such as work, shopping, and personal business each have their own daily pattern. The combination of these in an urban area results in an overall traffic pattern that seldom varies substantially within a subregion. The major variations from this pattern occur where there are large concentrations of specific land uses with a temporal pattern different from the overall pattern. Examples are industrial areas generating largely home-to-work and return trips or shopping centers generating a large proportion of their travel during the middle of the day. For land use proposals that create unique temporal patterns, the air quality analysis must initially address the question of temporal variations and determine whether significant changes to the surrounding pattern can be expected.

The land use and transportation modeling techniques required for the estimation of emissions differ for the three dimensions of subregional planning. The procedures for compilation of emissions inventories for each case are discussed in Sections E, F, and G of this chapter.

D. FACILITY AND OPERATIONAL PLANNING DECISIONS

1. Types of Facility and Operational Planning Decisions That Require Analysis at the Subregional Level

Decisions regarding facilities and operations plans represent direct changes to the transportation system. Since subregions often have implementing agencies, this category of transportation planning analysis has considerable applicability.

Three main types of activities are included in facilities and operations proposals: construction of new facilities, improvement of existing facilities, and operational changes. Table 4 lists examples of applications within each type and subregion. Since most facilities and operations proposals and decisions involve several of these types of activities, a particular analysis will invariably be concerned with a combination of them.

2. Required Air Quality Analysis

As with the land use category, the analysis procedures used for facility and operations planning depend on:

> Size of area. The three categories (subarea, corridor, and specific locality) describe the different types of area that may be involved.

> Planning time frame. Short range decisions can involve immediate proposals (3 to 5 years), whereas longer range plans may have projections 10, 20, or 30 years hence. The analytical requirements vary for different time frame situations.

> Quantification and data availability. Certain proposals can be readily quantified and have an ample data base. Others may require setting up basic quantitative assumptions so that the analysis can be carried out.

TABLE 4. EXAMPLES OF FACILITY AND OPERATIONS PLANS AND TYPES OF SUBREGIONS CONSIDERED IN ANALYZING THEM

Facility and Operations Plan	Type of Subregion		
	Subarea	Corridor	Specific Locality
New facilities			
New highway corridor	X	XX	
Existing highway realignment	X	XX	
Freeway access (interchange)	X	XX	XX
Arterial link	X	XX	X
Additions to local street system	XX	X	X
Rapid transit corridor	X	XX	
New bus routes	XX	X	X
Improved facilities			
Freeway lane increase	X	XX	
Interchange improvements	X	XX	XX
Arterial street reconstruction	XX	X	X
Local street upgrading	XX	X	X
Transit service upgrading	XX	X	X
Operations			
Freeway access control	XX	XX	XX
Coordinated street signalization	X	XX	X
Area-wide signal system	XX		
Traffic management strategies	XX	X	XX
Speed restrictions		XX	XX
Parking	X		XX
Transit priority treatment	X	X	XX
General			
City or area-wide circulation plan	XX		
Area-wide transit plan	XX		

XX = highly applicable.
X = some applicability.

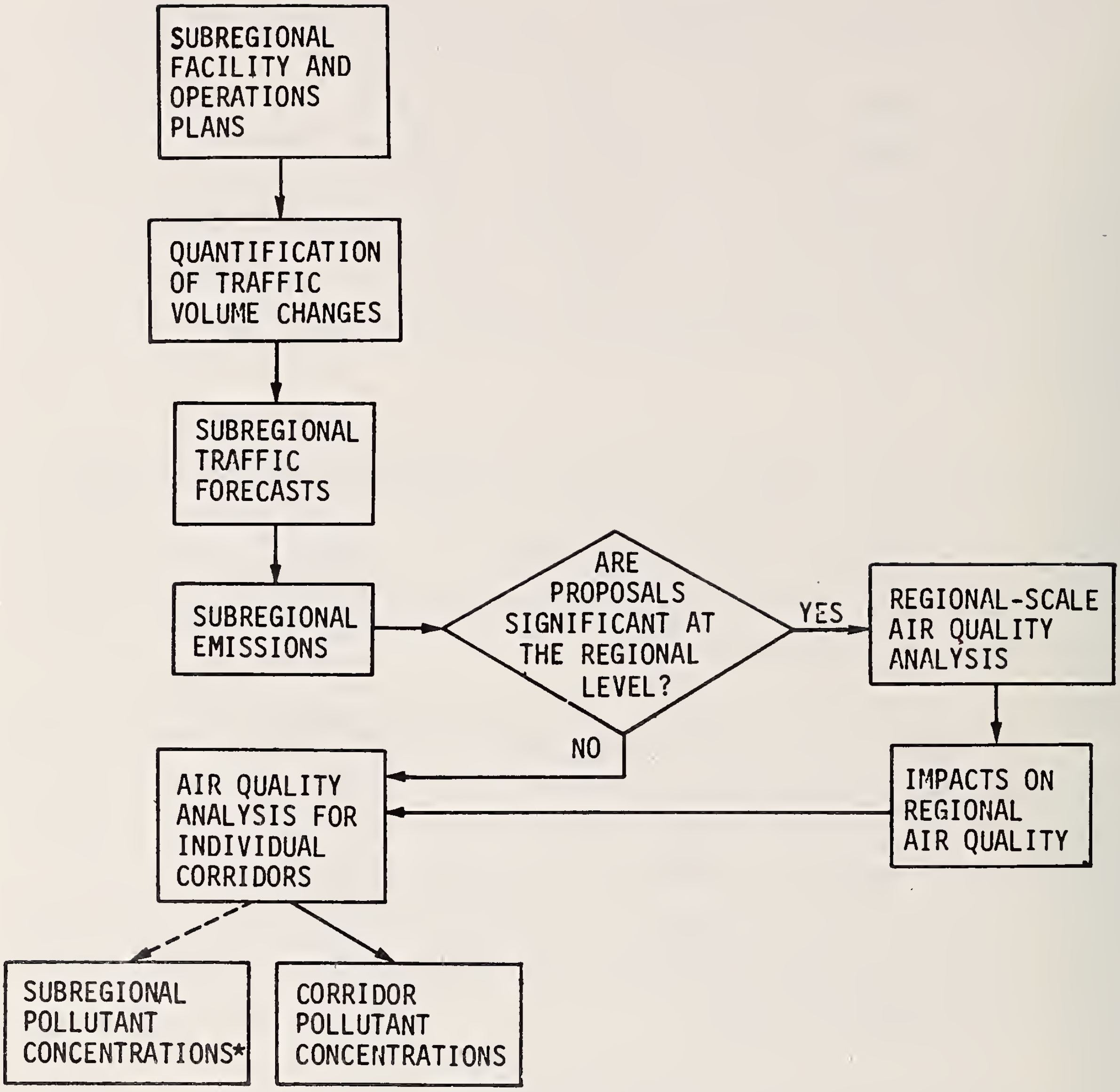
The size of area generally dictates whether a complete subregional model should be used or whether a specific locality simplified model can be used. (See subsequent sections of this chapter for a discussion of air quality analyses at the corridor, specific locality, and subarea level.) Similarly, the planning time frame determines the extent to which longer range forecast data will be needed. Data availability may be a key determinant in selecting analysis procedures. In most cases, however, data collection capabilities are a function of available resources. A preliminary analysis of the sensitivity of the proposed action to changes in emissions should therefore be made. In cases of high sensitivity, a data base should be established that can provide the desired level of reliability.

Figure 8 shows the basic process for investigating air quality as part of the analysis. Quantification of traffic volume changes involves using an appropriate forecasting procedure, as discussed earlier. This will produce the appropriate volumes, speeds, and levels of service for use in determining emissions.

As in the land use analysis, the significance of the proposals at the regional level is appraised. If necessary, a regional-scale analysis must be made to determine the effect on other portions of the region. Within the subregion, critical corridors are examined using a microscale air quality model. If the subregion is a combination of corridors, the same basic process is employed, but with cumulative effects considered in the air quality analysis process.

3. Estimation and Forecasting of Emissions

Most facility and operational planning activities have some effect on the spatial pattern of emissions. New facilities create new emissions corridors, but if traffic is diverted from other facilities, the change will largely be local. The greatest effect of facility and operations



* Represents accumulation over several corridors for subregions where this is necessary.

FIGURE 8. ANALYSIS OF FACILITY AND OPERATIONS PLANS AT THE SUBREGIONAL LEVEL

plans is to improve the quality of traffic flow. Thus, while the overall effect on VMT is minor, speeds and levels of service can be substantially affected, thereby reducing CO and hydrocarbon emissions. (Note, however, that NO_x emissions typically increase with increasing speed.) In contrast, the effects on temporal emissions patterns are minimal. The procedures for compiling the appropriate emissions inventory are described in Sections E, F, and G of this chapter.

E. AIR QUALITY ANALYSIS AT THE CORRIDOR LEVEL

1. Goals of the Corridor Analysis

In all likelihood, the focus of the corridor air quality analysis will be on the expected carbon monoxide concentrations in the immediate vicinity of the roadway. When defining the scope of the analysis, highway planners may find it helpful to consider several questions:

> How large is the corridor to be investigated?
> What time frame is of interest in the analysis?
> What degree of accuracy is needed in the analysis?
> How will the results of the analysis be used in the planning process and by whom?
> What resources are available to support the analysis?
> What standards will or might be used to judge the overall quality of the analysis and the results?
> What are the air quality problems and meteorological characteristics of the corridor?

Once the goals of the analysis have been established, highway planners can then define several tasks to be carried out, such as estimating future emissions levels or selecting an appropriate air quality model, in accomplishing the stated goals. In some instances, the goals of the analysis may be altered as further information becomes available or as an improved understanding of the problem is acquired. For example, in determining what future

emissions levels might be along a particular corridor, highway planners may find that a subregional or even regional analysis may be needed in addition to the corridor-level analysis of primary pollutants. Later, this section discusses criteria that might be used to assist in the determination of whether these additional analyses are needed.

2. Determination of Traffic Emissions

Invariably, a corridor analysis entails the identification of the maximum expected pollutant emissions levels along various segments of the corridor. Because emissions are directly related to traffic volumes, highway planners must determine the peak-hour traffic flow on the network as well as the percentage distribution of heavy versus light duty vehicles and the variation in speed throughout the day. In some cases, this information may be available from a calibrated transportation model, especially if the analysis focuses on modifications to an existing corridor or alterations to operational procedures. Where a new corridor is to be built, a transportation model, if it exists, might be adapted to include the new segment and traffic volumes, speeds, and so on obtained subsequently. If a model is not available, highway planners must use other means for estimating traffic configurations that would lead to peak pollutant emissions.

Consideration should be given to possible spatial variations in emissions rates along a given corridor. It is likely that there will be one or a few key locations at which emissions rates will be highest. These locations might be the confluence of two main arterial roadways, a steep grade, or a location at which dedicated bus lanes begin, thereby reducing the number of lanes available to light duty vehicles. Because the spatial variations in emissions along a particular corridor heavily depend on corridor configuration, analysis of spatial variations would be carried out irrespective of whether the planning concerns pertain to land use or facility and operations plans.

In contrast, estimation of the temporal distribution of emissions along a corridor may be easier for facility and operations planning decisions than for land use planning decisions. If the analysis concerns a modification to an existing corridor, some knowledge about the diurnal distribution of traffic volumes may already exist. However, if the analysis pertains to a new facility, a degree of uncertainty remains as to the number of vehicles that would use the corridor if it were to be constructed and how the traffic might be distributed on it throughout the day.

Once the traffic volumes, level of service, vehicle mix, vehicle speed distribution, and hot versus cold start distributions have been estimated, actual emissions rates can be determined for the corridor based on the emissions factors and projections given in the EPA's AP-42 document and its most recent supplements [5]. In some cases, highway planners may be able to obtain traffic data (e.g., vehicle mix, vehicle age distribution) for the corridor under study, or they may wish to consider the use of the emissions estimation techniques discussed in Chapter III of Volume I. Regardless of the approach followed, considerable care should be exercised to ensure that the best possible emissions estimates are obtained. Moreover, because the corridor analysis focuses on "worst-case conditions,"* the emissions estimates should pertain to traffic situations that could reasonably be expected to occur and that would lead to the highest overall emissions along the corridor.

Having estimated the emissions rates attributable to the corridor, highway planners are faced with an important decision: Do the projected emissions increases substantiate the need for further air quality analysis? In some cases, the answer is no. If the expected emissions increases for an existing corridor are very small (say, $\leq$ 5 percent) and air quality standards

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* Because the NAAQS for CO, total hydrocarbons, and oxidant are written in terms of concentration levels not to be exceeded "more than once per year," the meteorological and emissions conditions that could potentially combine to yield a violation might be considered "worst-case" conditions. Although it is unlikely that the worst possible emissions conditions would occur on the same day as the worst-case meteorology, the use of both together is consistent with the conservative philosophy used by the EPA in air quality modeling analyses.

are not known or suspected to be violated in the vicinity of the roadway, highway planners have some basis for foregoing further air quality analysis on the grounds that the increases are too small to cause any significant problem and that current analysis techniques are in all likelihood insensitive to such small changes in emissions rates. If the expected emissions increases are large (say, 50 to 100 percent), then some sort of preliminary screening procedure should probably be carried out. Rollback modeling is one possibility, though its range of applicability is limited; use of the so-called EKMA method may provide a more useful approach. Obviously, clear-cut guidelines cannot be given as to what constitutes a critical increase in projected emissions levels. If doubt exists as to whether the increases will be significant, the existing ambient pollutant concentrations should be examined and preliminary screening analyses should be employed. The EPA offers guidance on the use of such screening procedures in Ref. 9.

For new corridors, the problem is somewhat more complicated because highway planners do not have a benchmark for comparison. One possible approach to this problem is to apply line source Gaussian diffusion models (such as CALINE 2 [18]) to a similar existing corridor to determine projected increases in contaminant levels. Again, the decision as to whether an analysis should be carried out must be guided by the existing air quality at the proposed site. If existing air quality levels are near or at the standards, some form of modeling may be necessary.

3. Selection of Worst-Case Meteorology

Selection of the worst-case meteorology to be used in the corridor analysis entails identification of those meteorological conditions believed to be conducive to the occurrence of high CO concentrations near roadways. Data from numerous cities throughout the United States suggest that CO concentrations are generally highest in autumn, followed by summer, spring, and winter,* respectively [19], though air stagnation can occur during any

* The seasons during which highest CO levels are observed may vary from this order, depending on the meteorology of the region.

season. As one example, worst-case conditions occurring in the autumn might include light winds and a strong, low-level temperature inversion that persists for several hours; in other situations, a strong ground-based inversion may lead to worst-case conditions.

Historical weather records for the region containing the corridor should be reviewed to select the appropriate worst-case meteorology. Because light winds and limited vertical mixing are favorable to high CO concentrations, highway planners must pay particular attention to days characterized by these conditions. Often, several days in the historical record might be considered "worst case." When doubt exists as to which of several meteorological regimes could produce the highest CO concentrations, it is useful to consider several in the analysis.

Geographical and climatological considerations enter into the selection of worst-case meteorology. For example, an autumn day with light winds and a low-level temperature inversion might represent worst-case conditions in an urban street canyon. For a corridor leading to a congested resort area, worst-case conditions might occur under nearly calm, stable nighttime conditions when cold air drains down the corridor, pooling pollutants in low-lying pockets and hollows.

In some cases, historical weather data may be either insufficient or completely lacking. One approach to this problem is to examine meteorological records relevant to other corridors that exhibit characteristics similar to the one under study, such as proximity to a large body of water, similar synoptic weather patterns, and so on. Identification of worst-case conditions for an analogous corridor may be quite helpful. Occasionally, lack of data may necessitate assumption of worst-case conditions. If so, highway planners might use low wind speeds (1 to 2 meters per second) and the most stable atmospheric stability class expected along the corridor under these low wind conditions. For urban situations, this is usually Class "D" stability. Class "E" or "F" may be used for rural corridors.

Finally, the wind direction with respect to the corridor must be selected. Either parallel or cross-wind conditions can lead to the highest ground-level concentrations, depending on a receptor's distance from the highway. Generally, for receptors within the right-of-way line to 75 meters of the corridors, parallel wind directions will lead to the highest levels [18]. Beyond about 125 meters, cross-winds have the greatest adverse impact. In between these distances, both parallel and cross-wind directions should be considered to determine which leads to the highest concentrations [18].

4. Determination of Ambient Pollutant Concentrations

Selection of an appropriate ambient (or upwind) CO concentration for use in the corridor analysis poses several potential problems. First, quite often the nearest CO monitor is far from the corridor. If the nearest monitor is adjacent to a heavily used roadway, it may detect CO concentrations well in excess of those occurring in the vicinity of the proposed (or existing) corridor, particularly if the latter is in a suburban or remote area. Finally, in keeping with the worst-case analysis approach, it may be difficult to estimate what the ambient CO concentration would be under the worst-case meteorological conditions that are used in the study.

In the event that a CO monitor is not located sufficiently close to the corridor to be suitable for determining worst-case ambient concentrations at that site, highway planners have two options. One option is to institute a short term CO monitoring program at the corridor. Such an effort might be conducted for a period of two to six weeks during the time of year when the highest CO concentrations are expected. By comparing measured concentrations with those recorded elsewhere in the city, and by examining the long term historical record of CO concentrations, one can then estimate the annual frequency distribution of ambient CO concentrations in the corridor. Alternatively, highway planners might review the locations of the existing CO monitors in the region to determine which one most closely resembles conditions in the corridor of interest. If such a station exists, its record can be analyzed to estimate the suitable worst-case ambient CO concentration.

5. Selection of Appropriate Receptor Locations

A receptor site can be defined as a location in the vicinity of the corridor where ambient CO concentrations are of particular interest. Because federal standards are cast in terms of one-hour and eight-hour averaging times, it is appropriate to select sites where the public can reasonably be expected to be exposed to CO emissions for one of those time intervals. Typically, parking lots, access roads, intersections, tollbooth environs, and sidewalks are reasonable receptor sites.

In the process of estimating the worst-case emissions along the corridor, highway planners will normally be able to identify one or a few locations where emissions are the greatest. Surrounding these locations (e.g., access roads to parking lots, intersections), receptor sites can be chosen where the general public has access continuously for one- to eight-hour periods. These receptor sites can then be used in the main portion of the air quality analysis, which is discussed below.

6. Selection of Appropriate Analysis Methods

Selection of the model concept to be used depends on the study goals and the extent to which emissions, air quality, and meteorological data are available to support the analysis. Three general model concepts might be used in corridor air quality analysis: rollback, line source Gaussian diffusion modeling, and numerical grid modeling.

a. Rollback Modeling

If the goal of the corridor analysis is a preliminary screening of the impact of overall emissions increases or reductions along the corridor, in some limited situations, the rollback model may provide useful information. Before using this model concept, however, one should examine those conditions that strictly limit its range of applicability [20]. Finally, if the corridor does not currently exist or if the proposed modifications involve substantial spatial redistribution of emissions along the corridor, this model concept is inadequate. Note that in most applications the planner

will find that the rollback model is unsuited to his needs. It is discussed here primarily for the sake of completeness and because it has been used in the past, prior to the development of more sophisticated modeling approaches.

b. Line Source Gaussian Diffusion Modeling

The most widely used modeling concept for studying the microscale dispersion of air pollutants from line sources (corridors) is the Gaussian model. The widespread use of the Gaussian model is due not to the model's accuracy, but rather to its simplicity, minimal data requirements, and ease of use. Several line source diffusion models have been developed in the past, and more are certain to be developed in the future. The EPA currently endorses its own model, HIWAY, though it does not preclude the use of other models if necessary. HIWAY is a Gaussian plume model that computes the one-hour-average concentrations of nonreactive pollutants downwind of roadways. It is applicable for uniform wind conditions and level terrain. Although best suited for at-grade highways, it can also be applied to depressed highways (cut sections). (In many applications, the HIWAY model can be regarded as a conservative screening tool.) A similar model, CALINE 2, was developed and is used by the California Department of Transportation [18] and others.

Regardless of which line source model is being considered for use, it is extremely important that highway planners understand certain of the key assumptions of this model concept:

> The concentration field is invariant with time at any location. Therefore, the wind field and diffusivities cannot be a function of time.
> The wind field is spatially invariant.
> The turbulent diffusivity is spatially invariant in the horizontal and vertical directions. Moreover, this diffusivity is typically computed using correlations developed under one particular climatological regime and for flow over flat terrain.

> The source emissions rate is constant in time and spatially uniform along the line segment.
> The model is limited to wind speeds above 1 m/sec.

Undoubtedly, the Gaussian line source model concept is well suited to certain types of corridor analyses; for others it may be clearly inadequate. However, for many applications it may not be immediately clear whether the concept can be used or whether another, more sophisticated method is required. Under these circumstances, highway planners may find it necessary to seek consultation with experts familiar with air quality modeling, particularly in the use of the Gaussian and more complex models.

c. Numerical Grid Modeling

Under low wind speed conditions, when the vertical structure of the atmosphere is important, or when the highway configuration, terrain, and surrounding structures are complex, the Gaussian technique may not be adequate. Then, highway planners may consider the use of so-called numerical grid models. Substantially more complex than Gaussian models, this class of models solves the atmospheric diffusion equation using finite difference techniques. Several such models have been developed for application to corridors [21]. Owing to their more detailed treatment of atmospheric processes, these models incur greater costs of data preparation and simulation compared with Gaussian models. Thus, planners may elect to first consider line source models as preliminary alternatives (see Ref. 18 for a discussion of line source screening procedures). Then if line source models prove to be inadequate, use of a microscale grid model might be seriously entertained. If such a modeling approach is to be undertaken, the necessary data and technical competence required to operate the model must be available.

7. Adequacy of Analysis Techniques

The appropriateness of rollback, Gaussian, and grid models for relating traffic emissions and corridor CO concentrations depends on many factors, of which the following are perhaps most important:

- The environmental sensitivities raised by the project.
- The desired accuracy of the analysis.
- The resources (time, funding, technical competence, and the like) available to carry out the analysis.
- The data necessary to support the analysis.
- The complexity of the modeling problem.

At the time when the goals of the corridor analysis are set, highway planners should determine, as far as possible, the degree of accuracy desired of the analysis. In large measure, the desired accuracy will depend on the relative increase in emissions over existing levels and the existing air quality. Obviously, as the amount of projected emissions increases and as ambient CO concentrations approach the air quality standards, highway planners will seek progressively more accurate analysis methods. If an acceptable degree of accuracy is roughly within an order of magnitude, then rollback techniques may be appropriate if it can be demonstrated that the model concept is suited to the situation at hand [20]. If Gaussian techniques are used, highway planners might expect results accurate to within a factor of 2 or 3 of the correct value. If even more accurate results are needed, grid models might be used to obtain accuracies on the order of ±30 to 50 percent [22,23,24].

In applications with major meteorological, emissions, or topographic complexities, even the most sophisticated models may not be entirely suitable. If the meteorological or topographic complexities are such that the use of any available air quality model is precluded, an attempt should be made to acquire or improve the necessary data bases and to develop appropriate analytical techniques.

F. AIR QUALITY ANALYSIS FOR SPECIFIC LOCALITIES

1. Types of Planning Problems Encountered

The scope of specific locality air quality analyses is larger than that for corridors. In general, corridor analyses are often subsumed under specific

locality analyses, particularly if the latter contain two or more corridors directly affected by the specific locality planning problem. Examples of typical planning problems that might be faced are:

> Neighborhood zoning changes
> Local redevelopment plans
> Proposed commercial/industrial/residential centers
> New freeway facilities
> Freeway interchange improvements
> Alternative traffic operation strategies.

In some cases, the planning proposal may stem from land use planning activities; in other cases, the proposal may entail modifications to existing facilities (e.g., a freeway interchange) or operational procedures (e.g., ramp metering at a particularly congested interchange). The discussions below address air quality analyses that should be considered for specific localities regardless of whether they originate from land use planning activities or from facility and operations plans. Essentially, the only difference between the two categories is that in the former case it is often more difficult to quantify precisely traffic flow patterns, air quality, and so on.

2. Goals of the Specific Locality Analysis

The overall goals of this analysis are similar to those previously discussed in connection with corridor air quality analysis. To establish the goals of the analysis clearly, planners must identify the air pollutants of primary concern. As with the corridor analysis, carbon monoxide and particulates are of interest. However, secondary contaminants such as NO_2 and photochemical oxidants may also be of concern, because the specific locality may give rise to primary pollutant emissions of sufficient strength to affect concentrations of secondary pollutants downwind.

Formulation of the analysis goals also depends on whether the proposal involves a nonattainment area or one currently in compliance with air quality standards. Analyses of proposals in the former category may require a greater degree of accuracy than that normally required in determining allowable emissions increments in Class I, II, or III PSD areas. Prescription of analysis goals also depends on the relevant federal, state, and local air quality standards and regulations.

Finally, the goals must be set in light of what is economically and technically feasible. In some instances, available emissions inventories, analytical tools, and trained personnel may be more than sufficient to estimate the air quality impacts of a particular proposal. In other cases, insufficient emissions or land use information, lack of adequately trained personnel, or inadequate analytical tools may limit the goals set for the analysis. As discussed in Chapter III of these guidelines, highway planners should strive to take full advantage of the resources at their disposal, recognizing that in some instances the resources are inadequate to support a thorough, technically sound analysis. At a minimum, highway planners must identify the range of analysis options available and the factors that lead to the adoption of analysis goals and procedures.

Three examples of analysis goals that might be set for a land use planning proposal (such as a new shopping center) are:

> Estimation of the location and magnitude of the second-highest one-hour-average and eight-hour-average CO concentrations within or immediately downwind of the center.

> Estimation of the increase in oxidant concentrations downwind of the center in terms of both the spatial maximum and the total area over which oxidant levels are increased by, for example, 0.01, 0.02, and 0.04 ppm.

> Determination of the relative changes in air quality

to be expected in time, commencing with the construction phase and continuing to the time ETC + 20 years.

Of course, other concerns may be addressed as well. For example, under conditions of poor (but not necessarily worst-case) air quality, what are typical dosages encountered at neighboring receptors such as schools and hospitals?

3. Estimation of Traffic Emissions

Estimation of worst-case traffic emissions attributable to the proposal is indispensable to the air quality analysis. Emissions in a specific locality may be easier to obtain for facility and operations planning changes than for land use proposals. If the plan focuses on an existing facility (e.g., interchange or shopping center), highway planners should ascertain whether spatially resolved emissions inventories are available that include the location of the specific proposal. If a gridded inventory exists but is too coarse in resolution to permit an analysis of emissions changes expected as a result of the proposal, it may be necessary to disaggregate the inventory to provide the requisite spatial and temporal resolution.* If no inventory exists, except perhaps one based on the NEDS format for the entire AQCR, it may be necessary to develop an emissions inventory for the facility using either manual techniques (e.g., actual traffic counts) or an existing transportation model. (These techniques are discussed in detail in Volume I.)

When the planning proposal requires land use changes, analysis is more difficult. Little, if any, informtion is immediately available to establish baseline emissions conditions if the land use has not yet changed. In this case, highway planners might assemble growth forecasts, emissions factors, estimated modal split, and the like, and attempt to construct an emissions inventory. Alternatively, and perhaps more satisfactorily, worst-case emissions rates for the specific locality might be based on the assumption that the roadways in the interchange, shopping center, industrial

* Of course, the required resolution can be determined only by evaluating the analysis goals in light of available emissions information and the input requirements of the air quality model or models to be used.

park, or other facility are used to capacity. Knowing the design capacity of the roadway elements and assuming an appropriate level of service and vehicle mix, one can develop an inventory of emissions for the facility. (Of course, this approach is predicated on the assumption that a priori knowledge of the transportation system configuration is available.) Regardless of which approach is used, it will be difficult to estimate the impacts of land use proposals on traffic volumes (and hence vehicular emissions) in surrounding areas.

4. Ambient Air Quality Levels

Characterization of current ambient pollutant concentrations for specific locality analyses may often be easier than for corridor analyses because of the larger area under study. In many instances, routine air quality monitors may be located sufficiently close to the specific locality to provide a historical record of ambient concentrations, particularly for facility or operations plans relating to an existing network. For land use proposals where development currently does not exist, ongoing monitoring may not exist; accordingly, it may be necessary to estimate ambient levels from the results of field studies conducted under similar circumstances.

In addition to establishing baseline ambient air quality levels, highway planners must estimate ambient conditions at various stages throughout a project's life for later use in the air quality analysis. One approach to this problem is to investigate the historical air quality levels at the locale and to infer, from past trends and future projections, what future ambient levels might be. Factors including projected growth and increasingly more stringent emissions control regulations must be weighed when making air quality projections.

In some cases, another means exists for estimating future air quality levels. It appears that the use of regional air quality models will become more widespread in the years to come as the states revise their State Implementation Plans. These regional models will be used to assess the

effectiveness of alternative control measures and strategies in terms of meeting the NAAQS in various future years. If such an analysis has been carried out for the region containing the specific locality under study, the results might provide an alternative means for estimating future ambient air quality levels.

5. Selection of Appropriate Analysis Techniques

Selection of the most suitable air quality modeling technique largely depends on the goals originally set for the analysis. Often, highway planners will find it advantageous to carry out a screening procedure prior to committing themselves to a detailed analysis technique such as photochemical modeling.

The starting point in the screening process is a comparison of the emissions attributable to the proposal with those that would exist if the proposal were not implemented. Through the application of simple screening analysis such as rollback, modified rollback, isopleth techniques, or trajectory models, highway planners can develop a rough estimate of whether the proposal will cause or contribute to ambient concentrations in excess of the NAAQS. If simple screening procedures reveal little or no impact, more refined analyses are not required. In contrast, if the screening procedures indicate large impacts or if they are not appropriate for the analysis problem at hand, more refined procedures should be applied.

If refined modeling techniques are required for the specific locality analysis problem, selection of the appropriate method should be made with the assistance of expert consultation. Various models are available, ranging from relatively simple to complex. Although not yet recommended for routine use by the EPA, certain Gaussian mdoels (e.g., APRAC-1A) and certain of the more sophisticated trajectory models (e.g., ARTSIM, TRAJ) might be considered for use given the necessary data and technical competence. If photochemical oxidants are of concern or if the accuracy of simple Gaussian models is inconsistent with the analysis goals, complex

models may be needed. As an example, a photochemical trajectory model might be employed to assess the downwind effects on oxidant levels of a shopping center, freeway interchange, or sports stadium. Finally, trajectory models may not be suited to the meteorological or emissions characteristics of the area, or trajectory model output may not provide the requisite spatial resolution. In such cases, highway planners may wish to use grid-based photochemical models.

In the application of the more refined analysis methods to specific locality proposals, consideration must be given to the selection of suitable receptor locations. If data are available from existing monitors in the vicinity or downwind of the source area, these sites should be used as receptors in model verification efforts. However, once the model has been adapted to the area, highway planners must also select other reasonable "worst-case" receptor locations at which to investigate projected impacts. These sites may not necessarily be where monitors are currently located, but they should be where people are expected to be exposed to pollutant levels for the various averaging times under consideration.

6. Adequacy of the Analysis

A key issue highway planners must address is whether the specific locality air quality analysis is technically sound. Although it is impossible to stipulate procedures for making this judgment, certain questions should be borne in mind that may make the appraisal of adequacy easier:

> What is the accuracy of the emissions estimates to and from the locality and within it?

> Is the meteorological record of sufficient length (nominally five years) to permit identification of worst-case meteorological conditions that occur at the locality? (Also, are the data sufficiently representative of the overall subregion?)

> Are the assumptions and limitations of the particular modeling technique used well understood, and do any unique features of the locality make the use of the model inappropriate?

> What are the estimated accuracy and uncertainty bounds of the model predictions?

During the analysis, these and other questions should be addressed. Assumptions and approximations should be documented, and major decisions and the factors influencing them should be recorded. In so doing, planners not only build the foundation for a sound analysis, but also enable others who will be using the results to judge the quality of the analysis and the usefulness of the results in decision-making.

G. AIR QUALITY ANALYSIS FOR SUBAREAS

The air quality problems encountered in subarea transportation planning encompass certain aspects associated with both regional analyses and subregional corridor and specific locality analyses. On the one hand, determination of subregional oxidant levels may require knowledge of source emissions outside the subarea (or at least the concentration of urban pollutants transported into the area). On the other hand, estimation of primary pollutant impacts such as CO may necessitate the use of line source modeling techniques as part of the air quality analysis. Because a subarea impact study may involve regional as well as site-specific issues, highway planners may want to review the discussions on regional analysis in Chapter IV for the proper perspective.

1. Types of Planning Problems Encountered

The need for an air quality analysis can arise whether the transportation proposal involves land use plans, transportation policies, or facility and operations plans. Examples of each include:

> Land use--zoning changes to permit the development of satellite residential communities or industrial parks.

> Transportation policies--prohibition of automobile traffic in the central business district with conversion to public transit.

> Facility and operational plans--construction of a major freeway network in a portion of the metropolitan area.

A frequent characteristic of subarea planning problems is that they involve a single governmental or regulatory jurisdiction. For example, in a large metropolitan area containing several municipalities, one municipality may elect to modify its zoning ordinances, improve its transportation system, or in some other way alter the emissions patterns within its boundaries, thereby creating a potential subarea planning problem. In some instances, if the impact of the proposal is local and is contained within the municipality, a corridor-level or specific locality analysis may be indicated. In contrast, if the change in emissions patterns is great enough to have air quality impacts beyond the boundaries of the municipality (for example, downwind net ozone production), then a regional-scale analysis may be required. In between these two extremes lies the subarea air quality problem. In some cases, the distinction between subarea problems and those at other scales (particularly the regional scale) may be rather fuzzy.

2. Goals of the Analysis

In prescribing the goals of the air quality analysis, highway planners must determine whether the subarea is in a so-called nonattainment area for the NAAQS. If it is, then special attention must be paid to whether the proposed transportation system is consistent with existing or revised State Implementation Plans for bringing the area into compliance with the NAAQS by 31 December 1982. If the subarea falls within an area currently in compliance with the NAAQS, the air quality analysis should be designed to determine the extent of air quality degradation anticipated as a result of

the proposal and whether the emissions increases are within the limits of the PSD regulations to be promulgated by the EPA by 1979.

Typically, the pollutants of concern in a subarea air quality study include CO, NO_2, ozone, and hydrocarbons. In the process of estimating the potential impact of each pollutant, special attention should be focused on the accuracy of the analysis methods used and their suitability to the particular problem. In some respects, subarea studies are more difficult to perform than regional analyses. Whereas with regional studies the estimation of boundary conditions required by air quality models is generally straightforward (e.g., rural background concentrations are often used), for subareas boundary conditions must reflect the elevated pollutant concentrations found in urban areas. Thus, it is important to determine the extent to which uncertainties in the preparation of model inputs affect the resultant accuracy of model predictions. Finally, in establishing the study goals for the subarea problem, planners may find it helpful to address many of the same questions raised in connection with the corridor and specific locality analyses discussed earlier.

3. Estimation of Emissions

The degree of resolution in the subarea emissions inventory (both in terms of temporal and spatial scales and in source category identification) depends on the air pollutants under investigation, the meteorological complexity of the locale, and the degree of spatial homogeneity of the area-wide emissions patterns. For example, if CO impacts are of concern in a relatively flat urban area where the emissions patters are uniform and if box modeling is to be used, then a fairly coarse, aggregated inventory will probably be acceptable. In contrast, if photochemical oxidants are of concern and if the topography, meteorology, and emissions patterns of the area are complicated, then a spatially and temporally resolved inventory will be needed.

The procedures followed in preparing an emissions inventory for a subarea are almost identical to those for a regional analysis, as discussed in the preceding chapter. Normally, if the city for which the planning is being performed is one in which air pollution problems are of concern, another agency, such as the local air pollution control district or state air pollution control agency, is likely to have prepared some sort of emissions inventory already. However, because the available inventory may have been constructed to meet a different set of goals from those for the subarea study, planners must assess the extent to which the existing inventory meets their needs. It may be necessary for a joint working arrangement to be established between the transportation planning agency and the air pollution control agency to create an appropriate emissions inventory for the analysis. If an existing inventory must be modified, highway planners should pay careful attention to the required accuracy and spatial and temporal resolution of the emissions estimates that are to be used as input to the air quality model or models.

4. Selection of Worst-Case Meteorology

The air quality analysis should consider worst-case conditions. Often the worst-case meteorological conditions will vary depending on the pollutant under consideration. For example, the highest CO concentrations might be expected during very calm autumn or winter mornings when a strong, low-level inversion is present. Photochemical oxidants are typically highest during sunny summer afternoons. In selecting worst-case conditions for each pollutant, planners might find it profitable to review previous air quality records (say, two to five years) to identify several days on which high concentrations were observed. Analysis of the meteorological conditions associated with these days will facilitate the selection of reasonable worst-case meteorological conditions for use in the air quality analysis.

5. Ambient Air Quality Levels

Concurrent with the selection of worst-case meteorology, highway planners should also review available air quality data to ascertain pollutant concentration levels throughout the region that might be representative of ambient levels. In a regional air quality analysis, the difference in ambient (or background) levels between typical conditions and worst-case conditions is usually small because the background concentrations come from natural emissions and aged, diluted urban air masses. In contrast, the ambient or background levels used in a subarea air quality study are directly related to emissions from the metropolitan region containing the subarea. Because the meteorological conditions under study are "worst case," it can be expected that the background or ambient concentrations will be greater than those observed beyond the limits of the regional area. Thus, care must be exercised in selecting ambient concentrations for the analysis.

Because the air quality analysis may be carried out for various times in the future, it is necessary to estimate how the assumed ambient regional concentrations will vary in time. If a regional analysis has been employed earlier in the transportation planning process as a screening exercise, perhaps the projected regional air quality estimates can be used as an input to the subarea study. If not, future trends in ambient levels might be estimated from the most recent trends in the region of interest or from past trends and future projections for other similar urban areas.

6. Selection of Appropriate Analysis Techniques

Selection of the air quality model (or models) to be used for the subarea study depends on many factors, including the magnitude and geographical extent of the anticipated air quality problem, the pollutants and averaging time(s) of interest, the quality of the emissions estimates, and the availability of resources such as trained personnel, computer facilities, and meteorological and air quality data. Initial efforts should focus on the

use of screening procedures to estimate order-of-magnitude impacts. Rollback, modified rollback, EKMA, and perhaps simple box models may be useful in the preliminary screening process depending on the complexity of the particular air quality problem and the extent to which the screening model concepts are valid for the given application.

If photochemical oxidants are an issue, highway planners may find it necessary to utilize more sophisticated analysis techniques, such as trajectory or photochemical grid models. Although the EPA currently does not specifically recommend complex photochemical models, they are the only techniques available for analyzing oxidant impacts at the subregional level in most applications. Because of the highly specialized nature of the photochemical models, planners may need to seek advice from local or state air pollution control agencies or private consultants on the use of these tools.

Because photochemical air quality simulation models are expensive and require expertise in their use and because simple oxidant prediction methods are often inadequate predictors of secondary pollutants, the EPA is currently sponsoring research aimed at establishing a middle ground between these two categories of models. Efforts are under way to explore the feasibility of developing more accurate simple oxidant prediction methods and to simplify the air quality simulation models to the point where they are easier and less expensive to use yet still give acceptable results. Highway planners should consult with the regional EPA office to determine the status of oxidant prediction methodologies and to find out which of the available techniques the EPA favors.

7. Adequacy of the Analysis

When assessing the adequacy of the subarea air quality results, planners must consider many, if not all, of the questions posed in the earlier discussions concerning corridor and specific locality planning problems. Ideally,

highway planners will have established a certain requisite level of accuracy for the analysis when prescribing the study goals. To judge whether the desired degree of accuracy has been achieved, one may need to consider several measures of model performance depending on the type of model employed (i.e., grid, trajectory, or box model). Since the EPA is sponsoring research to determine a set of performance measures (and procedures for evaluating them), planners may benefit from consideration of these performance standards and procedures when assessing the accuracy of their analyses.

Appendix

SUMMARIES OF RELEVANT AIR QUALITY AND TRANSPORTATION LEGISLATION

This appendix presents brief summaries of the principal federal legislation affecting air quality analysis in transportation planning. The order of presentation follows that of Table 2 in Chapter II of this report. After the summaries is a bibliography of relevant legal materials.

> The Air Pollution Act of 1955 (PL 84-159, U.S. Congress, Washington, D.C., 1955).

This act established the first tentative federal step in the growing national concern for air quality. While protecting individual state rights, it grants Congress the ability to study the problem through actions undertaken by the Secretary of the DHEW. These actions have funded research studies and have awarded technical assistance to states and local jurisdictions upon request.

> Federal-Aid Highway Act of 1962, Section 9 (23 U.S.C. 134).

This section provides for federal financing and development of highway programs in cooperation with the states. It also established the continuing, comprehensive, and cooperative transportation planning process.

> The Clean Air Act of 1963 (PL 88-206, U.S. Congress, Washington, D.C., 1963).

This act expands and amplifies the federal role in controlling air quality. It encourages interstate agreement and intrastate actions in the regulation and abatement of air pollution.

It expands the role of the Secretary of the Department of Health, Education, and Welfare (DHEW) over that specified in the 1955 act to include grants of money for federal, state, and local programs that initiate abatement measures and, by amendment in 1965, authority to set standards for the control of air pollution.

> The Urban Mass Transportation Act of 1964, as amended, Section 14 (49 U.S.C. 1610, "Transportation").

This section declares national policy with regard to environmental protection in urban mass transportation situations. It basically restates the procedural requirements set forth in the National Environmental Policy Act with regard to the preparation of Environmental Impact Statements.

> The Motor Vehicle Air Pollution Control Act (PL 89-272, U.S. Congress, Washington, D.C., 1965).

Under this act, the Secretary of DHEW is granted the authority to establish regulations controlling vehicle emissions levels for new and future automobile models. It states that economic conditions and technical abilities are to be taken into consideration in reaching ecological judgments. The state of California is exempted, in that it is allowed to establish higher auto emissions standards.

> The Department of Transportation Act (49 U.S.C. 1651 et seq.).

This act established the Department of Transportation (DOT) and its rights and duties. The section that applies indirectly to air quality maintenance establishes the responsibility for developing "transportation plans and programs that include means to maintain and enhance the natural beauty of the land traversed" [PL 89-670, Sec. 4 (f)] in concert with the other concerned federal and state bodies.

> The Air Quality Act of 1967 (PL 90-148, U.S. Congress, Washington, D.C., 1967).

The 1967 act outlines a series of federal, state, and local measures to be taken and administered by the Secretary of DHEW. The Secretary is empowered to establish air quality control regions (AQCRs) within the nation based on geographic and atmospheric concerns, standards for these regions, and commissions to monitor and report on abatement activities. For the first time, the Secretary was enabled to seek redress through the Attorney General's Office in actions against individuals or jurisdictions not complying with federal regulations. Likewise, federal funds could directly be awarded to local projects, bypassing the more formal state control agency procedures.

> The National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.).

This act (called NEPA) establishes national policy on protection of the environment, requirements that environmental effects of major federal projects be reported in Environmental Impact Statements, and the Council on Environmental Quality (CEQ). The CEQ is required to report to the President of the United States on environmental problems and policies and to develop guidelines for implementation of NEPA. Current regulations promulgated by the CEQ establish procedures for assessing and reporting environmental impacts of federal projects. Proposed new regulations will simplify the reporting requirements and rationalize the environmental assessment process.

> The Clean Air Act of 1970 (42 U.S.C. 7401-7642, as amended).

This sweeping act combines all previous air and emissions acts into a single statute with the amplified powers necessary to cause abatement. It is administered by the Environmental Protection Agency (EPA). The greatest changes are in the requirements of the individual states to submit to the EPA air quality plans specifying the manner in which national primary and secondary ambient air quality will be achieved and maintained within each air quality control region in such state [PL 91-604, Sec. 109(A)], the power of the EPA to establish plans in states that fail to develop a plan, and the stringent (90 percent) reduction levels in auto emissions levels.

> Federal-Aid Highway Act of 1970 (23 U.S.C. 101 et seq., "Highways").

This act requires the Secretary of Transportation to develop guidelines to ensure that adverse environmental impacts of proposed highway projects are fully considered prior to approval of the projects. In this regard, the Secretary of Transportation is required to consult with the Environmental Protection Agency to ensure that highway development will conform to applicable air quality standards.

> The Clean Air Act Amendments of 1977 (PL 95-95, U.S. Congress, Washington, D.C., 1977).

These amendments to The Clean Air Act of 1970 reflect the basic changes in technical abilities and disabilities since the promulgation of the original act. They note and establish procedures

to deal with energy shortages vis-à-vis air quality (e.g., conversion to coal) and to set regulations for transportation planning programs that are designed to aid abatement. The amendments establish the National Commission on Air Quality, which reports directly to Congress on the technical, economic, and environmental "consequences of achieving or not achieving the purposes of this Act and programs authorized by it" [PL 95-95, Sec. 323(2)]. These amendments have made it necessary for the EPA to revise certain air quality regulations. New regulations have been proposed, but have not yet been adopted.

> Executive Order 11514, Protection and Enhancement of Environmental Policy (Office of the President, March 1970).

This order was issued by the President to implement the requirements of the National Environmental Policy Act. Among other important actions, this Executive Order established the EPA and its roles and functions. The order further required the Council on Environmental Quality to establish guidelines for preparation of Environmental Impact Statements.

> Executive Order 11991 (Office of the President, 1977).

This Executive Order issued by President Carter requires the Council on Environmental Quality to "issue regulations to Federal agencies for the implementation of the procedural provisions of the Act [NEPA] . . . designed to make the environmental impact statement process more useful to decisions makers and to the public; and to reduce paperwork and the accumulation of extraneous background data, in order to emphasize the need to focus on real environmental issues and alternatives." New proposed regulations have been promulgated, but have not been adopted.

> National Highway Traffic Safety Administration (NHTSA), "Motor Vehicle Emission Inspections" (49 C.F.R. 590, Office of the Federal Register, Washington, D.C., October 1975).

These NHTSA regulations establish the standards and proceduces necessary for motor vehicle emissions inspection by the individual states through their diagnostic inspection demonstration projects. These inspections help develop more effective regulation through the use of technical data and thus improve air quality.

> EPA, "National Primary and Secondary Ambient Air Quality Standards" (40 C.F.R. 50, Office of the Federal Register, Washington, D.C., July 1976).

These regulations promulgated by the EPA establish the primary and secondary ambient air quality standards for the various particulate substances judged by the EPA to be harmful to public health. Primary levels provide an adequate margin of safety to protect the public health. Secondary levels protect the public welfare from any known or anticipated adverse effects of a known pollutant. These regulations are being amended and supplemented as the result of The Clean Air Act Amendments of 1977. New proposed regulations have been issued, but have not yet been adopted.

> EPA, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans" (40 C.F.R. 51, Office of the Federal Register, Washington, D.C., July 1976).

These regulations promulgated by the EPA cover the technical details of air pollution control plans in their submission, content, requirements, and implementation. Air quality surveillance and monitoring methods are defined, and the various air quality maintenance area (AQMA) plan formats are analyzed.

> EPA, "Approval and Promulgation of Implementation Plans" (40 C.F.R. 52, Office of the Federal Register, Washington, D.C., July 1976).

These EPA regulations set forth extensive and detailed provisions to be included in individual state (and individual air pollution control districts within each state) air quality implementation plans. Of particular interest are the arrangement and review mechanisms of area designation and deterioration increments allowable under federal Class I (the most restricted) and Class II. Class III is designated for those areas where air standards are allowed to be no higher than the national ambient standards.

> EPA, "Prior Notice of Citizen Suits" (40 C.F.R. 54, Office of the Federal Register, Washington, D.C., July 1976).

This brief EPA regulation outlines the mechanisms available and the format utilized in the civil prosecution of violators of Section 304 of The Clean Air Act of 1970.

> EPA, "Energy Related Authority" (40 C.F.R. 55, Office of the Federal Register, Washington, D.C., July 1976).

Several waiver and variance procedures are outlined in these EPA regulations, which pertain to the ancillary problems of fuel shortages, for example, the burning of coal as an energy replacement for fuel oil.

> EPA, "Regulation of Fuels and Fuel Additives" (40 C.F.R. 80, Office of the Federal Register, Washington, D.C., July 1976).

These EPA regulations prescribe regulations for the control and/or prohibition of fuels and additives for use in motor vehicles and

motor vehicle engines. The regulations are based on a determination by the Administrator of the EPA that the emissions product of a fuel or additive will endanger the public health or will significantly impair the performance of a motor vehicle emissions control device that is either already in general use or developed to a point where in a reasonable time it could be in general use.

> EPA, "Air Quality Control Regions, Criteria, and Control Techniques" (40 C.F.R. 81, Office of the Federal Register, Washington, D.C., July 1976).

These EPA regulations list and geographically define the various air quality control regions in the United States.

> EPA, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines" (40 C.F.R. 85, Office of the Federal Register, Washington, D.C., July 1976).

These EPA regulations establish vehicle emissions regulations for all classes of motor vehicles and engines in 1976. They also list the recall procedures in effect for failure to comply with the regulations.

> EPA, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines: Certification and Test Procedures" (40 C.F.R. 86, Office of the Federal Register, Washington, D.C., July 1976).

These EPA regulations set forth the emissions standards for 1977 and later model year motor vehicles of all classes. They also outline and describe in technical detail the test procedures required for the certification of all new motor vehicles and engines.

> CEQ, "Preparation of Environmental Impact Statements: Guidelines" (40 C.F.R. 1500).

These guidelines state the principles and procedures to be followed in the preparation of Environmental Impact Statements and dictate the content of such statements required by the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.). Revised guidelines were ordered by the President pursuant to Executive Order 11991 (1977): They have been prepared but not yet adopted. The new proposed guidelines will simplify existing procedures, emphasizing the need for compact, succinct Environmental Impact Statements that can be read and understood by the public.

> CEQ, "Draft Regulations on National Environmental Policy Act" (Council on Environmental Quality, 12 December 1977).

These proposed new CEQ regulations were issued in compliance with Executive Order 11991 (1977). When adopted, they will replace current guidelines specified in 40 C.F.R. 1500. The proposed guidelines establish procedures to be followed by interested agencies in assessing, discussing, and presenting environmental issues, and they establish rules intended to simplify Environmental Impact Statements.

> FHWA, "Process Guidelines (for the Development of Environmental Action Plans)" (23 C.F.R. 795, Office of the Federal Register, Washington, D.C., 1974).

These regulations establish guidelines and review procedures for judging the social, economic, and environmental effects of the various proposed highway projects. Of particular interest is the emphasis placed on the development of alternatives for each proposed project, including the effect of the "no-highway

improvement option" [C.F.R. 795.9(b)1], and the systemized approach and forms available for providing public information on and input to the proposed projects.

- DOT, "Procedures for Considering Environmental Impacts" (DOT Order 5610.1B), U.S. Department of Transportation, Washington D.C., September 1974).

  This order outlines the procedures and mechanisms required in the preparation of Environmental Impact Statements for the various departments of DOT and for those agencies working for DOT.

- FHWA, "Urban Transportation Planning Process," in the "Federal-Aid Highway Program Manual" (23 U.S.C. 104(F)(3), 134, 315).

  This section describes the way in which to implement those portions of The Department of Transportation Act and the Urban Mass Transportation Act that require a continuing, cooperative, and comprehensive transportation planning process.

- FHWA, "Air Quality Guidelines," in the "Federal-Aid Highway Program Manual" (23 C.F.R. 770).

  This section outlines the policy and procedures concerning air quality followed by the FHWA to aid in the planning, location, and construction of highway improvements.

- FHWA, "Environmental Impact and Related Statements," in the "Federal-Aid Highway Program Manual" (23 C.F.R. 771).

  This section sets forth the regulations governing preparation and processing of Environmental Impact Statements and related statements by the FHWA for proposed highway improvements.

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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD–2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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R&D